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Volume 26, No. 12 December 1969

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JOURNAL OF THE FISHERIES RESEARCH BOARD OF CANADA

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Changes in Environment and Biota of a Natural Lake after Fertilization

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SMITH, M. W. 1969. Changes in environment and biota of a natural lake after fertilization. J. Fish. Res. Bd. Canada 26: 3101–3132.

When artificial fertilizers were added to unstratified, soft-water Crecy Lake (20 ha), New Brunswick, in three years (1946, 1951, and 1959), the lake was sufficiently self-regulatory that the artificial enrichments had only a temporary effect on organic production. The induced eutrophication proved largely reversible, with minor evidence of hastened senescence of the lake over an 18-year period. Each fertilization provided 210 ppb (parts per billion) of nitrogen (N), 390 ppb of phosphorus (P), and 270 ppb of potassium (K) to the water if the fertilizers were equally distributed throughout the lake.

The highest concentrations of total P, determined daily after the fertilizations in 1951 and 1959, were 220 ppb after 2 days and 192 ppb after 1 day, respectively. The concentration of inorganic P declined rapidly from about 150 ppb the day after the fertilizations in 1951 and 1959 to <10 ppb at a percentage loss per day of 5.5. Concentrations of organic P were highest 5 (80 ppb, 1951) and 8 (43 ppb, 1959) days after the fertilizations and declined to equilibration above prefertilization values for 3–4 months, and then to prefertilization values during the next years. Phosphorus lost in the drainage from the lake, assessed only in 1951 and 1959, was equivalent in these years to 8.5 and 12% of the amounts added in the fertilizers.

Limited observations indicated an increase of nitrate N in the water immediately after fertilization, but then a rapid loss. Deficits in dissolved oxygen were greatest under ice in the winters immediately after algal blooms induced by the fertilizers, but were serious in only about 30% of the volume of the lake. Specific conductance of the water exhibited minor change with fertilization.

Pronounced algal blooms, not previously recorded for the lake, followed each fertilization. Years of fertilization, and the next, were marked by blooms of *Anabaena*. Intensified growth of *Spirogyra* usually followed closely the blooms of *Anabaena*. In the 3rd year after fertilization algal growth was weak, at prefertilization densities. During blooms of *Anabaena* the numbers of zooplankters and bottom organisms, and growth of submerged, rooted aquatic vegetation, decreased. Zooplankton and bottom fauna were most abundant 2–4 years after fertilizations. Of the rotifers, three out of eight species became abundant. Of the planktonic microcrustaceans, *Leptodiaptomus* was always the most numerous; *Diaphanosoma* and *Daphnia* were more numerous after the last fertilization (1959) than they were earlier. Among the bottom organisms, *Hyalella*, chironomids, *Amnicola*, and sphaeriids increased most in abundance after the fertilizations.

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INTRODUCTION

A MAJORITY OF LAKES in New Brunswick and Nova Scotia, Canada, lie in hard rock formations, and have soft waters in which organic production is

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poor to mediocre (Smith, 1952, 1963). The waters of such a lake, Crecy, southwestern New Brunswick, were enriched with inorganic commercial fertilizers on three occasions (1946, 1951, and 1959). The primary objective was to improve the growth of brook trout (*Salvelinus fontinalis* (Mitchill)) and rainbow trout (*Salmo gairdneri* Richardson) and, as a result, their yield to anglers. Growth and yields were much improved when stocking, fertilization, and control of fish-eating birds and mammals were carried out concurrently (Smith, 1955, 1968).

This is a report on the changes that followed the fertilizations in the hydrographic conditions, and in the quality and quantity of the phytoplankton and zooplankton, rooted aquatic vegetation, and bottom fauna. Preliminary accounts of some of the changes that occurred after the first and second fertilizations have been given previously (Smith, 1948a, 1961).

DESCRIPTION OF CRECY LAKE

Crecy (Fig. 1) is a headwater lake of the Bocabec River system, tributary to Passamaquoddy Bay, southwestern New Brunswick (67°01′W; 45°14′N). Its elevation above mean sea level is 99 m (325 ft). The shortest distance to salt water is 6½ km (4 miles). Acidic Devonian rocks underlie the drainage area.

Physical features of the lake are as follows: area, 20.4 ha (50.4 acres); mean depth, 2.4 m (7.8 ft); maximum depth, 3.8 m (12.5 ft); volume, 0.49 ×

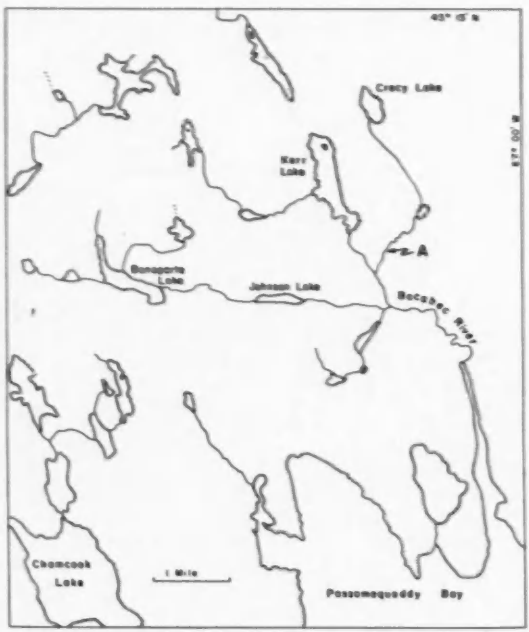

FIG. 1. Bocabec River system, New Brunswick, showing location of Crecy Lake, and sampling station (A) for phosphorus on Crecy outlet. (Canada Dept. Mines Tech. Surv. 1954. Natl. Topograph. Ser., New Brunswick and Maine, Sheet 21 G/3 East Half.)

10^6 m^3 (17.18 × 10^6 ft^3); volume development, 1.89; perimeter, 1.89 km (1.17 miles); shore development, 1.18.

The lake receives drainage from 1.6 km^2 (0.6 sq mile) of forested land, well covered with a mixture of conifer and deciduous species. The average annual precipitation, as recorded at the Biological Station, St. Andrews, N.B., 17.4 km (10.8 miles) from the lake, was 127 cm (50 inches) for the period 1946–62 (Table 1). Rainfall was not sufficient to maintain an outflow from the lake in the late summer and early autumn of the driest 5 years.

The average period of ice cover during the study (1946–62) was 130 days (range 104–146 days). The earliest and latest dates for freeze-up were November 27, 1949, and January 3, 1958. Those for the break-up were April 6, 1951, and May 3, 1961. The maximum thickness of ice each year (50–60 cm; 20–24 inches) was encountered in early March. At that time about the upper third of the ice cover consisted of frozen slush, formed from snow cover during previous periods of mild weather.

Data on the chemical conditions before fertilization (Table 2) were available from Leverin (1947) on the mineral content of the surface water for October 16, 1941, and from Smith (1952, and unpublished data) on sporadic observations of phosphorus, CO_2, dissolved O_2, oxygen consumed, *p*H, colour, and organic matter in bottom deposits during ice-free seasons from 1941 to 1946.

METHODS

Physical and Chemical Observations

Observations and water sampling were conducted at a marked, centrally located station, unless otherwise noted.

Subsurface temperature readings were taken with a Negretti and Zambra reversing thermometer calibrated to 0.2 degrees C. The *p*H readings were made colorimetrically with permanent Hellige standards. Free and fixed CO_2 concentrations were determined in the field by titration with N/44 Na_2CO_3 and N/44 HCl to the methyl orange end point in 1946. To measure specific conductance, a portable Solu Bridge, with an adjustable temperature compensator to correct readings to a reference temperature of 20 C, was used. Measurements were made before and after the fertilization in 1959, and during summers of the 3 following years.

Concentrations of phosphorus were determined by Deniges' ceruleomolybdic method with a Lumetron electric colorimeter (660-mμ filter; absorption cells with light paths of 20, 50, 100 and 150 mm depending upon the concentration of P). Analyses for inorganic P were made within 2 hr of collection of the samples. Concentrations of inorganic P below 5 ppb (parts per billion) were possibly overestimated (Rigler, 1966). Total P concentrations were determined from unfiltered samples digested with perchloric acid (Robinson, 1941). These determinations did not separate soluble organic P and seston organic P. To estimate the loss of phosphorus by drainage in 1951 and 1959, the entire outflow was passed through a rectangular flume installed just below the lake; the volumes of water discharged were calculated (Anderson, 1937) and the phosphorus contents determined until they reached prefertilization values. Determinations (34) of the phosphorus content at station A (Fig. 1) in the outlet, about 3.5 km (2.2 miles) below the lake, were made only from June 4 to November 12, 1959. Between the lake and station A the outlet stream fell 35 m (125 ft), and at one point enlarged into a shallow pond with an area of approximately 4 ha (10 acres).

Assessment of nitrate concentrations in the water was made by the strychnidine method (Zwicker and Robinson, 1944) in 1951. Precision with the strychnidine method was poor; duplicate analyses varied as much as 30% at concentrations of 25–30 ppb NO_3N.

TABLE 1. Monthly and annual precipitation (as rainfall in inches; 1 inch = 2.54 cm) at the Biological Station, St. Andrews, New Brunswick, for the years 1946–62. (Snowfall converted to rainfall by factor 0.1.)

Monthly

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	5.1	4.2	3.9	4.2	4.0	3.6	3.6	3.3	3.7	3.6	5.6	5.0
Range	2.6–10.4	2.2–6.8	1.3–8.1	2.1–7.6	0.9–7.5	0.8–9.3	1.4–5.4	0.5–6.7	1.1–8.7	0.3–7.1	2.6–9.7	1.1–9.2

Annually

Year	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Mean	32.1	41.2	46.3	43.8	56.5	60.8	51.5	59.1	68.2	38.4	46.2	41.0	53.0	60.0	54.4	46.9	47.5

TABLE 2. Chemical conditions in Crecy Lake before fertilization. Data largely from Leverin (1947) and Smith (1952). Data given as parts per million unless otherwise noted. All determinations were made when lake was free of ice.

Residue on evaporation (dried at 110 C)	23.8
Suspended matter	1.9
Silica (SiO_2)	1.5
Iron (Fe)	0.03
Calcium (Ca)	2.4
Magnesium (Mg)	0.7
Alkalis as sodium (Na)	3.6
Phosphorus (P): Total	0.014
Inorganic	<0.005
Sulphate (SO_4)	4.7
Chloride (Cl)	2.5
Total hardness (as $CaCO_3$)	8.9
Bicarbonate (HCO_3)	5.1–6.9
Free CO_2	0.8–1.1
Dissolved O_2 (mean for all depths of lake)	5.8–7.0 (92–99% saturation)
Oxygen consumed (permanganate digestion)	5.1–5.4
*p*H	6.6–6.9
Colour as Pt	≤5
Secchi disc	Bottom (3.5 m)
Organic matter in dried (60 C) bottom deposits (by ignition)	19%

PLANKTON

Algal counts were made directly on preserved (2% neutralized formalin) samples of surface water, and accordingly may not have been representative for all depths even when the waters of the lake are known to have been well mixed. Counts were made in a 1-ml Sedgwick-Rafter counting cell at a magnification of 224×. *Anabaena* spp. were recorded as strands of about 10 cells each.

Samples of zooplankton were obtained with a number 5 marquisette plankton net (26 meshes per cm; 66 meshes per inch), attached to a 30.5-cm (12-inch) ring. The net was towed at a depth of about 0.5 m for 15 min over a circular route in the central part of the lake, and a distance of about 500 m was covered with each tow. The volume of water strained by each tow approximated 3½ m^3. This method of collection does not take into account possible irregularities in the distribution of zooplankters in a shallow lake (Smith, 1952).

Samples were preserved with neutralized formalin and each was made up to 450 ml. The relative numbers of the various species of microcrustaceans were determined from counts in 10 1-ml subsamples. The remainder of each sample was centrifuged (Foerst centrifuge), and the weight of zooplankton determined after drying to constant weight at 60 C.

BOTTOM FAUNA

An Ekman dredge (511.5 cm^2; 81.0 sq inches) was employed to sample the bottom fauna at 10 stations, approximately equidistant from each other on the long axis of the lake. Depth of water at the stations varied from 1.5 to 3.0 m. Sampling was done on or about June 21, August 1, and September 21 in the years 1945 through 1956, and again in 1959 through 1963. A Petersen dredge (660.4 cm^2; 102.4 sq inches) was employed to obtain samples at 18 stations located in the littoral areas at <1 m depth from 1949 through 1954. One dredge haul constituted the sample at each station on a given sampling date.

The bottom material was washed in a set of three screens, the finest of which had 1-mm mesh. The material remaining on the screens was transferred onto a large white enamel tray, from which the living organisms were removed. The organisms, kept separate for each haul,

were preserved in 3% neutralized formalin, later enumerated into taxonomic groups, and finally dried at 60 C to a constant weight. Shell weights of *Amnicola* and *Helisoma* averaged 65% of their total dry weights, and those of Sphaeriidae 72%.

Fertilization

Inorganic commercial fertilizers, in a form available from local dealers, were added to Crecy Lake on June 19 and 20, 1946, June 20, 1951, and July 16, 1959. In 1959, because of heavy rainfall in June, application of the fertilizers was deferred for about a month in order to have approximately the same lake level and discharge from the lake as in 1946 and 1951.

The quantities of fertilizers in each application were sufficient to provide 210 ppb of nitrogen (N), 390 ppb of phosphorus (P), and 270 ppb of potassium (K) if uniformly distributed throughout the volume of the lake. The forms and quantities of the fertilizers have been reported (Smith, 1955, 1968), but they are again listed for ready reference, with quantities in pounds (1 lb = 0.45 kg), as follows: (1) June 19 and 20, 1946, ammonium phosphate (11% N; 48% P_2O_5) 2000, and muriate of potash (60% K_2O) 500; (2) June 20, 1951, ammoniated superphosphate (5% N; 17% P_2O_5) 4400, superphosphate (19% P_2O_5) 1000, and muriate of potash (50% K_2O) 600; and (3) July 16, 1959, ammonium nitrate (33.5% N) 530, ammonium sulphate (21% N) 200, triple superphosphate (46% P_2O_5) 1560, superphosphate (20% P_2O_5) 1210, and muriate of potash (60% K_2O) 500.

The fertilizers were broadcast in the dry, pulverized form in which they were received. About 75% of the quantities were spread over the shallow, littoral areas. The remainder was distributed over the central part of the lake. Distribution among emergent, rooted aquatic plants was avoided.

PHYSICAL AND CHEMICAL CONDITIONS AFTER FERTILIZATION

Water Temperature

The water of Crecy Lake was usually well mixed by wind during the ice-free seasons. On the 238 observation dates from 1946 through 1962 the surface exceeded the bottom temperature by more than 1 degree C only on 32 occasions, and by 2 degrees C on 10. The maximum observed difference was 3.9 degrees C on July 15, 1952, when the surface temperature was 26.9 C — the highest water temperature recorded during the study. The mean temperatures for July and August (52 readings for each month) were 21.7 ± 0.26 (standard error) and 21.3 ± 0.19 C for the surface, and 21.2 ± 0.23 and 20.9 ± 0.17 C for the bottom.

In summer and early autumn of 1946, 1951, 1959, and 1960, when dense algal blooms followed fertilizations, the mean difference between surface and bottom temperatures was 1.0 ± 0.20 degrees C. In other years the water was clear enough to see a Secchi disc at the bottom, and the mean difference for the same period of the year was 0.5 ± 0.08 degrees C. Though the means are significantly different at $P = 0.05$, any thermal stratification due to reduced light penetration with algal blooms was transitory.

In 7 of the 11 years when water temperature was obtained shortly after freeze-up, the lake had apparently frozen over with a sharp drop in air temperature during calm weather. The bottom temperature was not depressed below 4 C on these occasions. For instance, on December 17 in 1952, the temperatures at depths of 1, 2, and 3 m from the surface of the ice were 4.1, 4.1, and 4.5 C, respectively. The lake had frozen over during the night of December 11–12.

In the remaining 4 years the bottom temperature ranged from 1.9 to 2.7 C before the lake froze over. However, warming of the water, presumably from bottom deposits (the ratio of bottom area to volume of water in Crecy Lake is high, 1:8), and by insolation, was soon manifest. For example, the temperature of water at the bottom on December 19, 1950, was 1.9 C; by January 11, 1951, it had risen to 4.3 C. The mean winter water temperature under ice, as based on 67 observations from 1948 through 1962, was 3.2 ± 0.11 C at 1 m, 3.8 ± 0.09 at 2 m, and 4.2 ± 0.06 at 3 m (from surface of ice). A water temperature at the bottom somewhat above that for maximum density implies an unstable inverse stratification, with probably slow mixing throughout much of the volume of the lake.

Phosphorus

Concentrations of total P in the water

The concentrations were highest 2 days after the application in 1951 and 1 day after in 1959. The concentrations on these days at the central station on the lake were 220, 218, and 212 ppb at the surface, and 1.5 and 3.0 m, respectively, in 1951; and 192 ppb at the surface and 188 ppb at 3.0 m in 1959. Rapid mixing of added phosphorus throughout the lake was indicated by finding similar concentrations to those above at other points on the lake and in the outflow on the same dates. In 1946, the phosphorus content of the water was not determined until 8 days after fertilization, and the average concentration of total P for the surface and bottom water at the central station then was 183 ppb (Smith, 1948a). The above values include the concentrations of total P (largely organic P) that occurred naturally in the lake. Just prior to the fertilizations these were 15 ppb in 1946 (Smith, 1948a), 16 in 1951, and 10 in 1959.

The large differences between the theoretically possible concentrations and those recorded (183 ppb to 220 ppb in the 3 years) may have been due to sedimentation of phosphatic salts in situ into the bottom materials of the lake. Granular portions of the fertilizers sank rapidly to the bottom, and grayish patches of fertilizer materials were visible in the shallow water up to a month after the applications.

Concentrations of inorganic P in the water

The concentrations of inorganic P found in the water in 1951 and 1959 were highest on the day after fertilization and declined exponentially to approximately prefertilization values in about 40 days (Fig. 2). Inorganic P was not determined in 1946. The concentration decreased from 150 ppb on June 22 to 11 ppb on August 8 in 1951, and from 146 ppb on July 17 to 6 ppb on August 24 in 1959. For the rest of both of these years and those following, the concentrations continued at prefertilization values, about 5 ppb or less. In the winter of 1951–52, the one winter in which inorganic P was determined after a fertilization, the concentration also remained at 5 ppb or less. The rapid declines in concentration after the fertilizations were similar to those

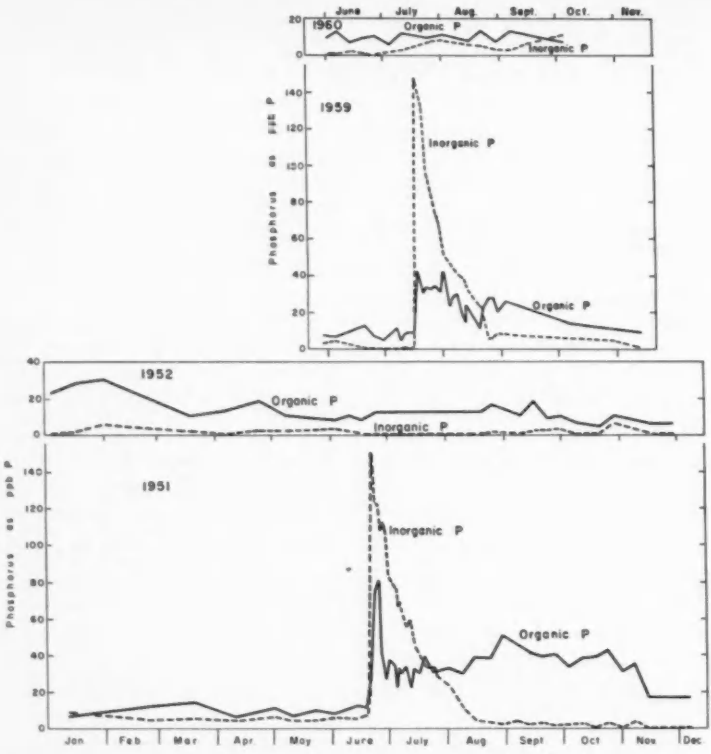

FIG. 2. Concentrations of inorganic and organic phosphorus in water in 1951, 1952, 1959, and 1960. Lake fertilized on June 20, 1951, and July 16, 1959.

found in both fresh and salt waters by Einsele (1941), Holden (1959), Nelson and Edmondson (1955), Orr (1947), Pratt (1949), and others. Eutrophication by isolated additions of fertilizers, at least in respect to phosphorus, is apparently not lasting and "has no permanent effect on the biochemistry of the lake, which evidently acts as a self-regulatory system returning to a steady-state condition determined by all the variables that operate within it, after one of these variables has been temporarily disturbed" (Hutchinson, 1957).

The exponential decrease in concentrations of inorganic P supports the concept (Hayes et al., 1952) that there is a continuous exchange of phosphorus between water and solids in a lake, as occurred when small amounts of radioactive phosphorus were added experimentally. The turnover times of P in the cycling between water and solids in Crecy Lake in 1951 and 1959, calculated (Hayes et al., 1952) for the period (40 days) evidently required for equilibration, were 18 and 19 days in water and 248 and 394 days in solids (Table 3). The calculated turnover time of 17 days in 1946 for phosphorus in the water phase may be too long, since the calculation (Hayes et al., 1952) was based on con-

TABLE 3. Rates of losses of inorganic phosphorus from water, and turnover times for phosphorus in water and solids, with three fertilizations of Crecy Lake. Calculations for 1946 from Hayes et al. (1952), based on data from Smith (1948a).

Year of fertilization	Loss per day of inorganic P from water (%)	Turnover time (*days*)	
		Water	Solids
1946	5.9	17	176
1951	5.6	18	248
1959	5.3	19	394

centrations of total P in water (Smith, 1948a; Fig. 3). Presumably Hayes et al. assumed that both inorganic and organic P concentrations declined in much the same manner from initial high values. For the 1959 Crecy data the calculated turnover time was 19 days, whether calculated on the basis of inorganic or total P concentrations. However, for the 1951 data, with concentrations of organic P holding at relatively high values after a rapid decline (Fig. 2), the turnover time was 18 days on the basis of concentrations of inorganic P and 29 days for concentrations of total P.

The turnover times of inorganic P in water were similar for the 3 years of fertilization, in contrast to an increase from 22 to 45 days for Lochan Darmh Mor, Scotland, when it was fertilized (Holden, 1959) in 2 consecutive years with superphosphate. Holden attributed the increase to partial saturation of the bottom mud with phosphorus, but no comparable cumulative effect was evident in the more widely spaced fertilizations of Crecy Lake. However, the turnover time for phosphorus in solids increased appreciably with each fertilization (Table 3), indicating differences both in kind of exchange system and in abundance and variety of the participating solids. Though Rigler (1964) found that the turnover time for inorganic P in water was longer in winter than in summer in nine Ontario lakes, on the basis of increases in concentration of inorganic P in winter, a comparable situation was not demonstrable in Crecy Lake since the concentration of inorganic P remained low (Fig. 2) during the two winters for which inorganic P in water was determined.

CONCENTRATIONS OF ORGANIC P IN WATER

Concentrations of organic P (soluble and particulate together) in water rose within 3 days from fertilization to maximum values of 80 ppb in 1951 and 43 ppb in 1959 (Fig. 2). The concentrations then declined to 25–35 ppm for 3–4 months in both years, and to prefertilization values during the summers of the following years (1952 and 1960). Similarly, in the 3 years after the fertilization in 1946 the concentrations of total P (Fig. 3), which in large part was organic P, approximated prefertilization values.

Differences in concentrations of organic P in water after the fertilizations in 1951 and 1959 could have resulted from differences in the character of the biotic systems most prominent at a particular time in exchanging phosphorus.

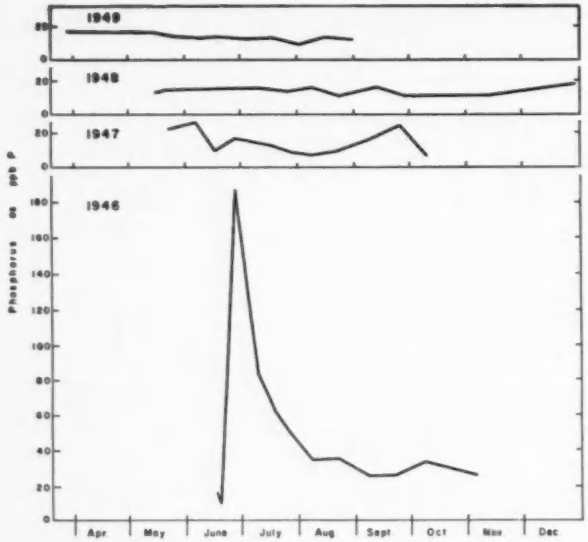

FIG. 3. Concentrations of total phosphorus in water from 1946 to 1949. Lake fertilized June 19 and 20, 1946. Data for 1946 previously reported by Smith, 1955.

The various systems exchanging phosphorus, such as bacteria, phytoplankton, and rooted aquatic vegetation, operate at different rates (Hayes and Philips, 1958).

The concentrations of organic P after the fertilizations in 1951 and 1959 suggest that equilibration in the exchange of phosphorus between water and solids occurred so that the total P (inorganic and organic) in water was maintained well above prefertilization concentrations for a period of time (4–5 months in 1951). However, the situation was temporary, since, as noted above, a year after each fertilization the total P (inorganic and organic) in water fell to and remained at prefertilization values.

LOSS OF ADDED PHOSPHORUS BY DRAINAGE FROM THE LAKE

The estimated loss of total phosphorus (above the concentration of 15 ppb, the average value before the fertilizations) by drainage from the lake was 8.5% of the amount added in 1951 and 12% of that in 1959, when there was a somewhat greater outflow than in 1951 at and after fertilization. Evidently a large proportion of the added phosphorus remained in the lake, presumably sedimented, not exchanging between water and solids, and contributing little, if any, to a sustained increase in eutrophication of the lake.

PHOSPHORUS IN THE WATER OF THE OUTLET STREAM

After the fertilization in July 1959, the total P concentrations in the outlet stream at the sampling point 3.5 km below the lake trended upward, but only to concentrations that indicated a minor influence from the quantity of phosphorus being discharged from the lake (Fig. 4). The inorganic P con-

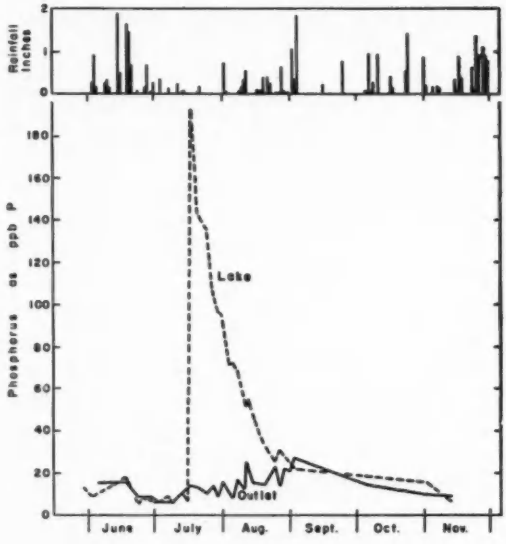

FIG. 4. Concentrations of total phosphorus in lake and in outlet at Station A (Fig. 1), and rainfall, June–November 1959.

centrations remained at about 3 ppb, with no trend to higher concentrations, during the entire period of the observations (about 5 months). The augmented phosphorus content of the water as it left the lake was apparently quickly reduced in the outlet stream (and its small pond) to stabilized values normally characteristic of the outlet water. Analyses at the time of increased outflow in October and November because of heavy precipitation did not indicate increased concentrations at the sampling point.

NITROGEN (NITRATE)

The concentration of nitrate nitrogen rose sharply, but briefly, to about 45 ppb immediately after the lake was fertilized on June 20, 1951 (Fig. 5). The concentration was then low from early July to early September, when observations ceased. The rapid but short-lived increase in NO_3 N coincident with the 1951 fertilization suggests that some NO_3 N was contained in the fertilizer even though nitrogen was theoretically present only as the ammonium ion ($Ca(NH_4)_4$ $(PO_4)_2$) in the nutrients put into the lake in that year. Higher concentrations of NO_3 N, to a maximum of 81 ppb, were found earlier in 1951, in February and March under ice (Fig. 5).

Algae can utilize the ammonium ion as a source of nitrogen, particularly in soft waters such as in Crecy Lake (Hutchinson, 1957). Doubtless the ammonium nitrogen in the three fertilizations contributed to the dense blooms of *Anabaena* that developed after each fertilization. Blooms of blue-green algae, such as *Anabaena circinalis*, have been considered to be indicators of a high nitrogen content in water (Prescott, 1939).

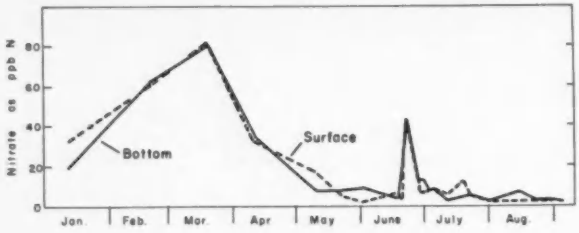

FIG. 5. Concentrations of nitrate nitrogen in surface and bottom waters of lake in 1951. Lake fertilized June 20, 1951.

POTASSIUM

What happened to the potassium in the fertilizers was not studied, nor was information obtained to show whether the added potassium contributed to the increased productivity. It was assumed with the first fertilization in 1946 that effective commercial N–P–K land fertilizers would also be effective in lake waters, and, although no positive effect upon organic growth was established, potassium was retained in the fertilizers applied in 1951 and 1959 to make the three fertilizations comparable in this respect. There was no evidence that added potassium contributed to increased algal growth that followed the fertilization of Michigan lakes (Barrett, 1957) and Scottish lochs (Holden, 1959).

CARBON DIOXIDE, CARBONATES, AND *p*H

Coincident with the bloom of *Anabaena* that followed the fertilization in 1946, the carbon dioxide content of the water fell from 1 to virtually 0 ppm, and the bound CO_2 increased from 3.0 to 4.4 ppm (Smith, 1948a). Though blue–green algae blooms are most frequently associated with hard waters, abundant blooms of *Anabaena* followed enrichment of soft-water Crecy Lake with nitrogen and phosphorus. Apparently the low content of bicarbonates was not a serious limiting factor in *Anabaena* growth when a relatively abundant supply of other nutrients was provided by fertilization.

The *p*H value of Crecy Lake water varied narrowly between 6.6 and 6.9 in years after fertilization when algal growth was poor, as it had before fertilization. With algal blooms it rose to 8.2 in 1946 and 7.8 in 1951 and 1959 (Fig. 8–10). The *p*H was depressed in winter under ice to low values of 6.1 in 1952 and to 6.3 in 1960, when there was an observable high content of decomposing algae in the water after algal blooms that persisted into early winter.

SPECIFIC CONDUCTANCE

The low specific conductance, 20–30 μmhos/cm, in Crecy Lake was in keeping with the naturally poor mineralization of its waters, and appeared little affected by fertilization and subsequent alteration of environmental conditions. Each fertilization added considerable quantities of electrolytes to the water (about 230 ppm of solids of varying solubility if evenly dispersed

throughout the lake). However, the addition of fertilizers in 1959 was followed by only minor fluctuations in conductivity of the water (Fig. 6). Conductivity was little, if at all, affected by algal blooms in 1959 and 1960. It did not follow the upward trends in *p*H values (Fig. 6) that were coincident with the development of these blooms.

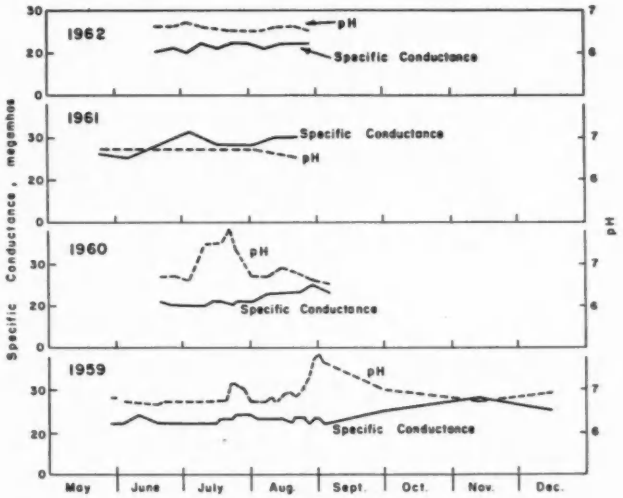

FIG. 6. Specific conductance and *p*H of lake water, 1959–62.

DISSOLVED OXYGEN

During the ice-free season the dissolved oxygen content of both the surface and bottom water was most frequently above 90% saturation (Fig. 7). Supersaturation was found coincident with the vigorous rate of growth and photosynthetic activity of algal blooms as they developed after each fertilization (Fig. 8–10). However, these high oxygen contents were not sustained throughout the periods of the blooms. The concentration waxed and waned, apparently reflecting a changing growth vigor by the algae as the blooms progressed. The highest oxygen content was not always an index of the highest algal counts. Though the oxygen content of the bottom and surface water usually approximated the same value, it was depressed in the bottom water, but not seriously, during algal blooms, particularly when the water of the lake was occasionally not well mixed throughout during calm, warm weather of late summer. Minimal observed saturation values in the bottom water were 65% on September 19, 1951, 69% on August 3, 1959, and 53% on August 22, 1960.

During the winter, under ice the oxygen content of the bottom water was at times depressed to levels which, if not lethal, were debilitating to fish. The most serious deficits (Fig. 7) occurred during winters following heavy algal blooms. However, when serious deficits occurred in the bottom water, deficits in the surface water under ice were comparatively minor. There was always

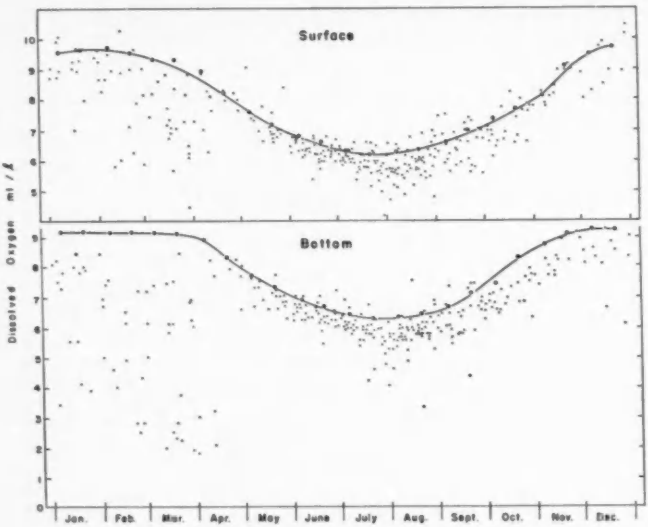

FIG. 7. Concentrations of dissolved oxygen in surface and bottom waters, 1946–62. Solid line indicates saturation values at mean biweekly temperature of water.

sufficient dissolved oxygen for fish in the surface metre of water (Fig. 7), which was about 70% of the volume of the lake.

ALGAE

Dense growths of *Anabaena* and *Spirogyra* followed each fertilization even though these algae were normally minor constituents of the algal flora and did not previously form conspicuous blooms. Numerous species of desmids characterize the flora of Crecy and neighbouring soft-water lakes (Hughes, 1949; Smith, 1952). However, these and other algae, aside from *Anabaena* and *Spirogyra*, responded in a relatively minor way, if at all, to the fertilization.

ANABAENA

Blooms of *Anabaena* developed to various densities and within various periods of time after the three fertilizations.

In 1946 and 1951 strong blooms developed in 6–8 weeks (Fig. 8, 9). In 1959 a minor bloom was manifest within 10 days, but this largely disappeared, to recur more strongly after 2 weeks (Fig. 10).

Anabaena blooms in the years of fertilization continued into autumn and even early winter. That in 1951, for instance, was still evident in the water in holes cut through the ice until late in January. By that time *Anabaena* was senescent, and present only as minute, discrete clumps. These disappeared by January 28, to leave the water contrastingly clear.

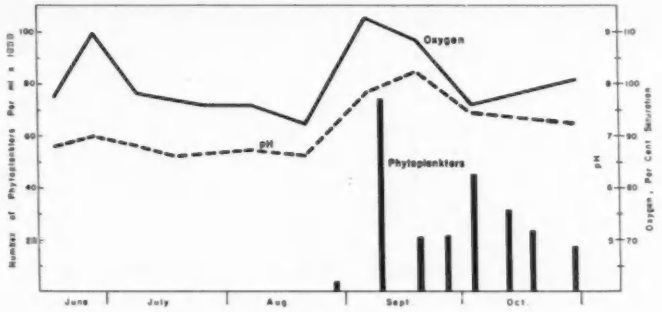

FIG. 8. Numbers of phytoplankters, dissolved oxygen contents and *p*H of water in 1946. Lake fertilized June 19–20, 1946. Data for phytoplankters previously recorded by Smith, 1948b.

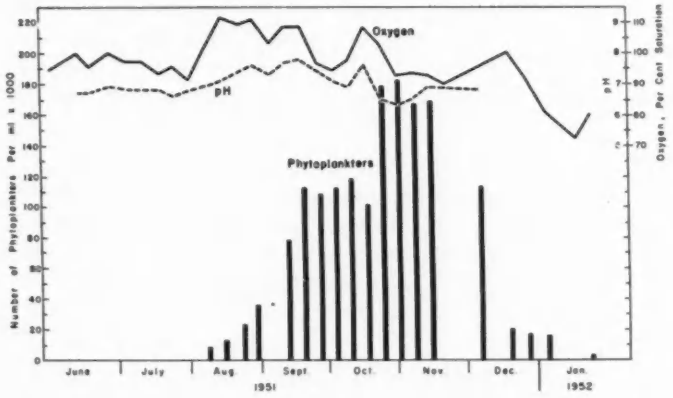

FIG. 9. Numbers of phytoplankters, dissolved oxygen contents and *p*H of water, 1951–52. Lake fertilized on June 20, 1951.

Blooms of *Anabaena* occurred as well during the year after each of the three fertilizations. In 1947 and 1952 they were weak and of short duration, the highest counts being 2700 strands per ml in May 1947, and 3000 strands per ml in June 1952. In both years the blooms had disappeared by late July, and the water then became clear with minor growth of planktonic algae, *Anabaena* or others. In contrast, a bloom of *Anabaena* in 1960 was very dense by late June and was present until early September (Fig. 10). Whereas all previous blooms consisted almost entirely of *Anaebena circinalis*, that in 1960 was predominantly *Anabaena flos-aquae*.

No blooms of either species of *Anabaena* occurred during the third or later years after each fertilization.

Strong blooms of *Anabaena* were not evident after the fertilizations until the concentrations of inorganic P were again low. The blooms in the years

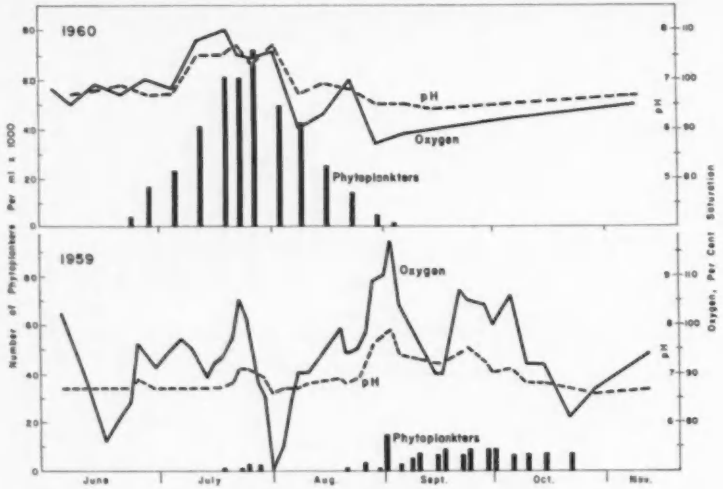

FIG. 10. Numbers of phytoplankters, dissolved oxygen contents, and *p*H of water, 1959–60. Lake fertilized July 16, 1959.

after fertilization occurred when concentrations of inorganic P were at pre-fertilization values. Though other biosystems, and bottom materials, rather than growth of *Anabaena* were evidently primarily responsible for the rapid decline in concentration of this nutrient in the water, sufficient inorganic P remained available to support very strong blooms of *Anabaena*.

Spirogyra

Spirogyra, whose abundance was roughly gauged by frequency and size of clumps, grew profusely in Crecy Lake after each fertilization, but tended to follow blooms of *Anabaena*. Thus, in August 1947, after recession of the weak bloom of *Anabaena* in July, many clumps of *Spirogyra*, up to 0.5 m across, made their appearance. This alga was again found in 1948 and 1949, but in decreasing abundance. It did not occur in observable clumps in 1950. Large quantities of *Spirogyra* were again present from May to July 1953, 2 years after fertilization in 1951, but it was scarce, or apparently absent, in the years 1954–58. Unlike the above occurrences in years following fertilization, *Spirogyra* became abundant in August 1959, a year of fertilization. Its occurrence in that year was between two blooms of *Anabaena*, and was for a short period of about 3 weeks. No clumps of *Spirogyra* were noted in 1960 or 1961, but a few in 1962; none was observed in 1963.

Other Algae

Anacystis (*Aphanocapsa*) sp. occurred, but not consistently, with the blooms of *Anabaena*. Counts were usually less than 1000 colonies per ml.

Dinobyron sp. reached a maximum count of 2500 colonies per ml during July 1961. Colonies of *Nostoc* spp., lying on the bottom of the lake, were taken in the bottom fauna dredgings at 1–3 m depth (Table 4). These algae were common before fertilization (September 1945, and June 1946). Except for a high count in September 1947, their numbers declined and remained well below pre-fertilization values. *Nostoc* spp. appeared to be clear-cut examples of algae that were adversely affected by the environmental changes that followed the fertilizations. Less light penetration with blooms of *Anabaena* may have been a factor in their reduced numbers. (A Secchi disc disappeared at depths less than 1 m when the blooms were dense.) However, they did not recover in the clear water between fertilizations. Other species of algae, as gauged from sporadic samples taken between periods of blooms, responded little, if at all,

TABLE 4. Total numbers of colonies of *Nostoc* spp. in 10 bottom samples (511.5 cm^2) taken annually from central part of lake on or about June 21, August 1, and September 21. No collections in 1957 and 1958, or in June and August 1945.

Year	June	Aug.	Sept.
1945	–	–	1050
1946	3240	1410	660
1947	480	1280	5780
1948	600	965	970
1949	45	200	420
1950	195	200	170
1951	59	59	84
1952	35	41	22
1953	10	33	105
1954	94	125	98
1955	16	35	14
1956	12	6	35
1959	14	12	6
1960	123	117	76
1961	10	10	35
1962	195	145	120
1963	33	8	18

to the enrichment of the lake, and no counts above 500 cells per ml were recorded. However, various algae, in addition to those that tended to bloom in Crecy Lake, have been found to respond to the fertilization of other soft-water lakes (Langford, 1950; Brook and Holden, 1957; Holden, 1959).

ROOTED AQUATIC VEGETATION

The quantities of rooted aquatics as a whole increased modestly over the 18 years of observations that encompassed the three fertilizations. Though quantitative assessments were not made, it was readily observed that certain species listed in the appendix were favourably, although others were unfavour-

ably, affected by the fertilizations. At no time were rooted aquatics a prominent feature of the organic growth in Crecy Lake.

The most plentiful submerged aquatic, *Isoetes*, appeared moribund with each algal bloom, as gauged by material brought up in a bottom dredge. Increasing abundance of healthy plants was noted each year after algal blooms, and after three fertilizations *Isoetes* covered more of the bottom than before enrichment, but the species was becoming less abundant by 1963. Also concurrent with the algal blooms, the submersed threadlike leaves of *Juncus militaris* died, and few flowering spikes were produced. Unlike *Isoetes*, *Juncus* did not recover well after the setbacks with each algal bloom, so that the quantity of this species was decidedly less in 1963 than before fertilization in 1946. *Potamogeton*, *Eriocaulon*, *Nuphar*, and less common species seemed little favoured by the fertilization. An exception was *Sparganium augustifolium*, which increased in abundance from a few plants before fertilization to conspicuous, yet not dense, beds at one end of the lake by the termination of observations.

In contrast to observations at Crecy Lake, Weatherley and Nicholls (1955) observed a marked increase in the abundance of rooted aquatic vegetation in a small, unproductive Tasmanian lake when it was enriched with N–P–K fertilizers, plus crushed limestone, in 2 consecutive years. They considered that limestone, not added to Crecy Lake, favoured organic decomposition and availability of nutrients, particularly phosphorus, to rooted aquatic plants.

ZOOPLANKTON

Quantities of Zooplankton

The average dry weight of zooplankton in the comparative tows taken during the ice-free season tended to be greater ($P > 0.05$) in 1949 and 1950 than in the 1st year of fertilization, 1946, or in 1947 (Table 5). However, the quantities increased ($P < 0.01$) after the second fertilization in 1951, particularly in 1953 and 1954, over those found during the period from 1946 through 1950. Still greater average quantities were found in the 2nd and 3rd years after the third fertilization in 1959. There was some suggestion of a cumulative effect, resulting in increasing quantities of zooplankton, with the successive fertilizations. However, the higher quantities did not persist. In general, the quantities of zooplankton increased to highest values during the 2nd–4th years after the fertilizations, but then there were recessions in the quantities, in keeping with the reversion of the concentrations of phosphorus and in the quality and quantity of phytoplankton, toward prefertilization values.

Depressions in the quantities of zooplankton were consistently observed as each bloom of *Anabaena* developed (Table 5; Fig. 8–10). *Anabaena*, and other myxophycean algae, reportedly provide poor direct grazing for zooplankters (Edmondson, 1966; Straškraba, 1966; and others). Aside from the

TABLE 5. Mean monthly dry weights in grams of zooplankton in plankton net tows at 0.5 m (3.5 m³) from central part of lake, 1946–62. Numbers of samples given in parentheses. Lake fertilized in 1946, 1951, and 1959.

Year	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for year	SE of mean
1946	–	0.49(5)	0.91(5)	1.69(6)	0.75(7)	0.40(6)	0.15(5)	0.30(4)	–	0.70	0.124
1947	0.53(1)	0.63(5)	0.51(5)	0.94(3)	0.74(3)	0.95(3)	0.58(3)	0.47(1)	–	0.68	0.065
1948	0.34(1)	0.40(5)	0.13(3)	0.53(4)	0.21(1)	0.34(2)	0.09(2)	1.00(3)	1.20(1)	0.46	0.084
1949	0.98(2)	0.80(3)	1.74(4)	0.73(5)	0.10(5)	0.35(4)	1.08(5)	1.60(3)	–	0.87	0.154
1950	0.58(1)	0.29(4)	0.84(4)	0.78(4)	1.88(5)	0.83(4)	0.75(4)	0.44(4)	1.34(2)	0.88	0.116
1951	0.58(4)	0.33(4)	0.58(7)	0.76(4)	1.23(6)	0.38(4)	0.17(5)	0.04(2)	–	0.58	0.086
1952	0.11(1)	0.28(3)	0.80(4)	1.29(5)	1.26(4)	2.52(5)	2.50(3)	2.62(3)	–	1.44	0.193
1953	0.93(2)	1.28(1)	3.75(4)	1.70(5)	1.34(3)	1.86(3)	1.80(1)	3.17(1)	2.09(1)	2.06	0.337
1954	1.51(1)	0.31(1)	0.90(1)	1.44(2)	1.19(1)	1.63(4)	5.67(2)	4.56(1)	–	2.25	0.506
1955	1.03(1)	0.65(2)	0.68(2)	1.40(3)	1.18(3)	0.74(2)	0.67(2)	1.33(1)	–	0.97	0.133
1956	0.04(1)	0.82(2)	1.28(1)	3.52(1)	1.84(2)	0.67(2)	0.32(2)	–	–	1.10	0.274
1957	–	0.48(2)	2.05(1)	0.60(3)	–	–	–	–	–	0.80	
1958	–	–	–	0.91(3)	0.69(1)	–	–	–	–	0.86	
1959	–	0.70(1)	0.94(6)	4.52(6)	2.78(8)	0.56(8)	0.52(5)	1.42(3)	–	1.81	0.325
1960	0.08(1)	0.41(1)	3.52(4)	5.54(4)	3.62(5)	1.77(2)	5.09(1)	6.27(1)	–	3.67	0.514
1961	–	–	3.72(2)	5.30(2)	2.02(2)	–	–	–	–	3.68	
1962	–	–	1.82(3)	1.79(5)	1.92(4)	–	–	–	–	1.84	0.261
1946–62	0.66	0.51	1.38	2.03	1.60	0.97	1.06	1.43	1.49		

poor status of these algae as a food for zooplankters, their blooms result in marked changes in the physical and chemical environment, and even if short-termed, as in Crecy Lake, these changes may be inhibitory. Smith and Moyle (1945) found that production of microcrustacea was poor when blooms of blue-green algae dominated the phytoplankton in fertilized Minnesota fish ponds. However, blooms of *Anabaena* provide much decomposable organic matter, and thus, directly or indirectly through attendant bacteria, are acceptable to many zooplankters as food (Darnell, 1964; Gunkel, 1968; Hillbricht-Ilkowska et al., 1966). Blooms of *Anabaena* that resulted from fertilization of Crecy Lake doubtless contributed to the increases in quantities of zooplankton in the 2nd–4th years after fertilization.

The heavy growth of *Spirogyra*, which occurred in more or less discrete clumps after the blooms of *Anabaena*, did not appear to have an adverse effect upon the zooplankters, even if the environment within the clumps of *Spirogyra* was possibly unfavourable.

Composition of the Zooplankton

The zooplankton taken in the net hauls consisted largely of rotifers and microcrustaceans (Appendix 1).

Rotifers

Kellicottia longispina, *Trichocera cylindrica*, and *Conochilus unicornis* were the most numerous rotifers. Although the three species were consistent in being scarce during heavy algal blooms, their abundance was erratic after the algal blooms subsided. *Kellicottia* was scarce when *Conochilus* was the only abundant species (1956–57), or when *Conochilus* and *Trichocera* were both numerous (after the fertilization in 1946). The comparative counts of *Kellicottia* were <5, or it was absent, in the samples taken from 1946 through 1950, and again from 1957 through 1960. Counts of this species ranged from 35 to 950 in the spring and autumn samples from 1951 through 1956, and from 45 to 200 in the spring samples in 1961; it was scarce in the July and August samples of any year. *Trichocera*, in counts ranging from 35 to 89, was common only in the spring and autumn from 1949 into 1951. *Conochilus* occurred in modest numbers from 1946 through 1951 with counts ranging from 27 to 107; the species became most abundant in 1956 and 1957 when a maximum count of 7440 was recorded on May 31, 1956. *Conochilus* flourished in summer as well as in spring and autumn, e.g., counts were 6000 on July 20, 1956, and 475 on August 27, 1957.

Other species of rotifers (Appendix) were encountered sporadically in most years of the study, but counts were usually <5. *Asplanchna priodonta* was present in 1946; it was scarce or most frequently absent from samples in subsequent years. *Ploesoma lenticulare* was a common rotifer in Crecy Lake during the summer of 1942 (Smith, 1952) but it was not recorded during the period when the lake was fertilized. Aside from the consistent scarcity of all

rotifers with algal blooms, it is apparent that the species in the lake responded variously to the environmental changes that followed each fertilization.

MICROCRUSTACEA

Leptodiaptomus minutus was the most abundant microcrustacean in the plankton (Table 6) and, as a result, largely determined the changes in the total quantity of zooplankton (Table 5). A similar dominance of *Leptodiaptomus* has been noted in neighbouring but unfertilized lakes (Smith, 1952). Only *Diaphanosoma* and *Daphnia* among the other planktonic microcrustaceans in Crecy Lake (Appendix) increased appreciably in numbers, and then belatedly with the third fertilization. The ratio in numbers of *Daphnia dubia* to *Daphnia pulex* in most samples was about 10:1. The predator *Mesocyclops edax* exhibited some but no marked response to increases in quantities of other zooplankters, some of which were probably species preyed upon.

TABLE 6. Average comparative numbers of microcrustacean plankters in net tows taken annually at 0.5 m (3.5 m^3) from central part of lake, 1946–62. Hauls in 1957, 1958, and 1961 mainly restricted to June, July, and August (see Table 5). Lake fertilized in 1946, 1951, and 1959.

Year	No. tows	*Mesocyclops*	*Leptodiaptomus*	*Epischura*	*Diaphanosoma*	*Daphnia*	*Bosmina*
1946	38	15	266	3	28	41	2
1947	24	22	269	1	12	5	<1
1948	22	6	299	2	3	8	3
1949	31	18	623	6	11	6	5
1950	32	21	682	12	9	6	17
1951	36	40	412	6	24	4	6
1952	28	131	903	14	5	4	2
1953	21	15	1204	4	5	8	4
1954	13	12	1450	10	10	5	6
1955	16	19	722	6	8	5	7
1956	11	27	917	11	15	9	9
1957	6	6	614	5	17	3	15
1958	4	80	563	8	85	5	54
1959	37	38	866	14	110	108	13
1960	19	93	1372	6	213	88	<1
1961	6	96	1490	2	186	454	3
1962	12	45	1094	9	6	169	2

The population of adult *Leptodiaptomus* usually increased rapidly in early spring, and reached peaks of abundance in June and July. The species exhibited lesser peaks of abundance in autumn. This seasonal pattern is similar to that observed for this species in Lake Nipissing, Ontario, by Langford (1938). The other planktonic microcrustaceans in Crecy Lake were largely aestival. The dominance of *Leptodiaptomus* at all seasons, however, was illustrated by the monthly average percentage by count, consolidating the data for all years, as follows: April, 98; May, 87; June, 84; July, 85; August, 78; September, 90; October, 97; November, 98. There was no particular

upsurge to dominance by less common species as among the algae, e.g., *Anabaena* and *Spirogyra*, with the fertilizations, or change in dominance as with the rotifers. The numbers of all the microcrustaceans in the plankton were depressed during blooms of *Anabaena*.

BOTTOM FAUNA

Central Part of Lake (1.5–3 m in Depth)

The number and dry weight of bottom organisms in the central part of the lake increased after each fertilization. Highest numbers and greatest weights usually were found during the 2nd and 3rd years after each fertilization (Table 7). Thereafter there was a decline toward prefertilization values. Rise and decline in weight and number of organisms with years from each fertilization

TABLE 7. Numbers and dry weights in milligrams of bottom organisms in 10 hauls taken on three occasions annually with an Ekman dredge from central part of lake. One haul (511.5 cm^3) on each occasion at each of 10 stations equal distances apart on long axis of lake at depths of 1½–3 m. No sampling in 1957 and 1958, and in 1945 sampling only in September. Lake fertilized in 1946, 1951, and 1959. Data for 1946–56 repeated from Smith (1961). Factor for conversion of data to number and weight per m^2 is 1.955.

Year	June 21		Aug. 1		Sept. 21	
	No.	Wt	No.	Wt	No.	Wt
1945	–	–	–	–	319	176
1946	546	292	1013	335	1472	485
1947	338	211	262	238	1759	856
1948	630	362	722	658	2789	1153
1949	1065	680	1374	658	2512	1174
1950	548	329	453	200	632	259
1951	582	288	888	300	345	265
1952	582	360	1230	773	2623	1097
1953	1067	849	1008	493	2578	1342
1954	2275	907	1083	581	3262	1174
1955	1306	570	1014	544	3352	1274
1956	607	385	555	377	471	350
1959	947	390	740	269	999	358
1960	914	594	1103	732	1555	524
1961	368	350	1033	619	1667	473
1962	1050	529	1524	485	2509	890
1963	572	313	531	392	923	435

proved to be a quadratic curvilinear relationship. For weight, the coefficient of multiple correlation, R, was 0.478, and for number, 0.578, with $P < 0.01$ in each case (three variables and 45 df) (Snedecor, 1946). For the data obtained with first two fertilizations, R was 0.659 for weight and 0.518 for number ($P < 0.01$; three variables and 30 df) (Smith, 1961). However, the favourable effect of the fertilizations was short-lived. No cumulative effect with the successive fertilizations was evident.

COMPONENTS OF THE BOTTOM FAUNA

The bottom organisms responded variously in time and in degree to the pronounced changes in the physical and trophic environment that followed the fertilizations (Table 8). Variations in numbers of prominent forms over the period 1946–56 have been shown graphically by Smith (1961).

The amphipod *Hyalella azteca* was dominant in most years (Table 8). The species is secretive and closely associated in its distribution with rooted aquatic vegetation (Gaylor, 1922). In Crecy Lake it was notably associated with *Isoetes*. When the growth of *Isoetes* was adversely affected by blooms of *Anabaena*, particularly by that in 1951, the numbers of *Hyalella* in the samples significantly fell (Table 8). Low concentrations of dissolved oxygen in the bottom water during winters following algal blooms (Smith, 1968) may also have contributed to the reduced numbers of *Hyalella*. However, there was a sharp reduction in numbers of *Hyalella* from early August to late September, 1951 (Table 8) without the oxygen content at the bottom falling below 5.7 ml/liter.

Midge larvae (predominantly Chironomidae) increased modestly in numbers after the first fertilization (Table 8). Standing crops of chironomids were comparatively high with the second and third enrichments. These short-term peaks of abundance were associated with large amounts of organic detritus produced by the intense blooms of *Anabaena*. Trophic conditions for these detritus-feeding chironomids (Johannsen, 1937) were accordingly much improved, with an apparent favourable effect.

Other bottom organisms also became more plentiful after the fertilizations, but in varying abundance with the three fertilizations (Table 8, 9). Sphaeriids flourished in 1949, quite out of proportion to any other year. Oligochaetes attained maximum abundance in 1952. A heavy bloom of *Anabaena* seemingly favoured the oligochaetes, but resulted in unsuitable conditions for sphaeriids.

Except for *Hyalella* and *Amnicola*, records of number and weight are for taxonomic groups, each of which was comprised of a number of species. Accordingly, it is not known whether groups as a whole, or certain species in them, accounted for the observed peaks in abundance. However, in the case of the sphaeriids it may be assumed that all species were adversely affected when the group as a whole became scarce after the second fertilization (Table 9).

LITTORAL AREAS (<1 M IN DEPTH)

Number and dry weight of organisms in the littoral areas increased after the fertilization in June 1951, reaching a peak in the total weight in 1952 (Table 10). For most forms, with the notable exception of *Hyalella*, numbers and weights decreased in the following 2 years. *Hyalella* increased in abundance each year, without exhibiting the setback so pronounced in the deeper water at the time of the dense algal bloom in 1951. Rooted aquatic vegetation in the littoral areas, such as *Eriocaulon* and *Lobelia* with which *Hyalella* was also closely associated, was little affected by this algal bloom. The chironomid

TABLE 8. Total numbers of components of bottom fauna in 30 Ekman dredge hauls taken annually from central part of lake, 1946–63. One haul (511.5 cm^2) at each of 10 stations equal distances apart on the long axis of the lake at depths of 1½–3 m on or about June 21, August 1, and September 21. No sampling in 1957 and 1958. Lake fertilized in 1946, 1951, and 1959. Factor for conversion of data to number and weight per m^2 is 1.955.

Year	Planar-ians	Oligo-chaeta	Hirudinae	*Hyalella*	Hydra-carina	Odonata	Chiro-nomids	Other insects	Gastropods	Sphaeriids
1946	69	23	8	2436	34	16	80	75	182	108
1947	7	27	28	1696	9	9	220	78	253	32
1948	9	41	56	2750	22	45	343	214	413	248
1949	27	49	40	2662	19	37	145	136	193	1643
1950	17	38	14	1015	26	19	82	77	133	212
1951	41	110	7	907	49	14	274	148	223	42
1952	6	928	3	135	193	7	252	114	517	10
1953	12	148	33	2746	111	1	1292	60	207	111
1954	42	173	48	5572	106	3	424	133	67	52
1955	106	55	25	4494	80	16	341	132	326	97
1956	18	68	7	740	74	6	200	68	378	74
1959	27	152	27	1964	56	2	168	59	160	71
1960	31	123	25	1526	77	8	1182	105	401	94
1961	24	61	40	2159	216	5	159	61	259	84
1962	69	170	37	4074	75	9	161	112	176	200
1963	1	116	33	991	83	8	410	63	160	161

TABLE 9. Total numbers of four prominent components of bottom fauna in 10 dredge hauls taken on three occasions annually with an Ekman dredge from central part of lake, 1946–63. One haul (511.5 cm²) on each occasion at each of 10 stations equal distances apart on the long axis of the lake at depths of 1½–3 m. No sampling in 1957 and 1958. Lake fertilized in 1946, 1951, and 1959. Factor for conversion of data to number and weight per m² is 1.955.

	Hyalella			Chironomids			*Amnicola*			Sphaeriids		
	June 21	Aug. 1	Sept. 21	June 21	Aug. 1	Sept. 21	June 21	Aug. 1	Sept. 21	June 21	Aug. 1	Sept. 21
1946	361	879	1196	9	9	62	61	52	64	76	8	24
1947	202	136	1358	33	22	165	53	58	135	10	11	11
1948	383	345	2022	50	48	245	75	119	134	59	56	133
1949	600	782	1280	42	38	65	97	57	30	230	413	1000
1950	295	296	424	37	10	35	23	66	42	109	39	64
1951	311	558	38	158	114	67	37	36	151	24	13	5
1952	14	21	100	284	821	1417	132	214	166	5	2	3
1953	259	497	1990	559	363	370	127	59	16	14	2	27
1954	1927	774	2871	164	151	109	9	28	18	9	15	28
1955	836	694	2919	229	35	44	102	99	98	31	25	41
1956	242	235	263	88	77	35	98	164	107	36	25	13
1959	689	529	746	65	32	71	53	52	55	22	32	17
1960	432	607	487	192	92	898	114	231	50	29	51	14
1961	151	610	1398	76	64	19	31	156	66	15	24	45
1962	743	1161	2170	69	76	16	29	51	80	39	52	109
1963	67	185	739	271	113	26	61	68	28	67	70	24

TABLE 10. Numbers and dry weights (mm) of various groups of bottom fauna in 18 hauls of Petersen dredge (660.4 cm²) taken in August, 1950–54, in littoral areas (<1 m depth) of lake. Factor for conversion of data to number and weight per m² is 0.841.

	1950		1951		1952		1953		1954	
	No.	Wt	No.	Wt	No.	Wt	No.	Wt	No.	Wt
Planarians	14	7	75	43	72	32	29	13	33	18
Oligochaetes	54	13	88	24	113	37	115	41	59	17
Hirudinae	9	13	20	17	20	66	38	247	30	112
Hyalella	515	56	885	138	1052	201	2181	263	3017	362
Hydracarina	9	5	45	19	28	9	17	5	26	10
Odonates	21	125	36	370	30	300	13	109	12	68
Chironomids	73	8	242	22	1084	267	160	10	250	16
Other insects	92	32	222	108	336	81	102	42	155	86
Gastropods	58	85	49	65	104	283	84	122	38	55
Sphaeriids	17	13	24	36	12	20	22	45	12	19
Totals:	862	357	1686	842	2851	1296	2761	897	3632	763

population fluctuated much as in the deepwater areas. Relatively large insect nymphs (dragonflies, mayflies, caddisflies) contributed more substantially to weight of bottom fauna in the littoral areas.

The weight of bottom organisms per square meter in August samplings (1950–54) was greater in the deeper water (1.5–3 m) than in the littoral areas in 4 of the 5 years, the numbers and dry weights (mg/m²) being as follows:

	1950		1951		1952		1953		1954	
	No.	Wt	No.	Wt	No.	Wt	No.	Wt	No.	Wt
Littoral	725	300	1418	740	2398	1090	2246	754	3054	642
Deeper water	886	391	1736	587	2405	1511	1971	964	2117	1136

However, the ratios in weight and number per square meter between the deepwater and littoral areas was less than 2:1 for all 5 years.

GENERAL DISCUSSION

A very significant finding following the spaced fertilizations of Crecy Lake was the efficiency of the lake in self-regulating its biochemical processes whereby added nutrients, at least phosphorus, were removed from biotic cycling in the lake. Eutrophy induced by the fertilizations receded toward the original oligotrophic condition. Only a small portion of the added phosphorus, for instance, apparently contributed to development and continued sustenance of organic growths. Quantities of phosphorus equivalent to about 10% of that added could be accounted for in the outflow. Most remained in the lake, presumably sedimented in bottom muds and unavailable to limnetic plants. Each fertilization doubtless made some contribution to the senescence of Crecy Lake, but so far as could be observed with three fertilizations spaced over an 18-year period, this was very minor. Certain conditions prevailed throughout the study and contributed to regression of the lake habitat to the prefertilization state. For the most part the habitat of this shallow lake remained in an oxidized state, so that the added phosphorus could be held out of the biotic cycle as the poorly soluble ferric phosphate. Further, the drainage area remained unaltered woodland.

In contrast to the situation in Crecy Lake, it has been well documented that the aging of lakes is accelerated and limnetic habitats for many animals degraded by eutrophication resulting from continuous and uncontrolled disposal in them of domestic and industrial wastes rich in plant nutrients (Lackey and Sawyer, 1945; Hasler, 1947; Langford, 1965; Hasler and Swenson, 1967; Thomas, 1968). Oxygen deficits become increasingly greater and, if prolonged and sufficiently severe, the cool-water salmonids are eventually eliminated. Thus, with annual applications of fertilizers, fertilization of Michigan trout lakes resulted in some instances in a higher production of trout, but there was evidence of cumulative unfavourable oxygen deficits (Tanner, 1960). With spaced (5 and 8 years apart) fertilizations of unstratified Crecy Lake, organic growths were stimulated, and these culminated in a better growth

of trout (Smith, 1955, 1968), with temporary reduction of the dissolved oxygen content to harmful values for trout only in the bottom water during the winters following algal blooms.

From the viewpoint of resource development, inorganic fertilizers were added to Crecy Lake to improve growth and yield of trout to anglers. Crecy is similar to many unstratified lakes in the Maritime Provinces of Canada, the waters of which support brook trout in low numbers per unit area, basically because of poor trophic conditions (Smith, 1963). Attempts to improve trout angling appreciably by introductions of hatchery-reared young into such habitats have largely failed (Smith, 1948b, 1952). It should not be anticipated that these essentially oligotrophic lakes would respond otherwise, without manipulation of the environments to provide better living conditions for trout. The fertilization of Crecy Lake increased the quantities of trout foods, and an improvement in growth of introduced and native young trout ensued. However, benefits of the faster growth rate and greater production of trout were poorly realized by anglers until predation by birds and mammals was sharply curtailed (Smith, 1955, 1968). Then, the benefits of fertilization were more fully manifested. The improved growth rate of trout resulted in planted underyearlings (age 0) attaining a suitable size for angling when yearlings (age I), and, with protection from predators, up to 40% of the number of planted underyearlings were cropped by anglers during the year after their introduction.

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APPENDIX 1

List of Identified Plants and Animals from Crecy Lake

For the most part the plants and animals were taken in routine sampling for the above study. No special biotic survey was made. Identifications by persons named in parentheses.

PLANTS

Algae. See Hughes (1949) and Smith (1952) for recent lists of phytoplankters in Crecy and neighbouring lakes.

Higher aquatic vegetation (Science Service, Department of Agriculture, Ottawa)
- *Fontinalis dalecarlica* B. and S.
- *Isoetes muricata* Dur.
- *Sparganium eurycarpum* Engelm.
- *Sparganium angustifolium* Michx.
- *Potamogeton epihydrus* Raf.
- *Sagittaria graminea* Michx.
- *Eriocaulon septangulare* With.
- *Pontederia cordata* L.
- *Juncus militaris* Bigel.
- *Nuphar variegatum* Englm.
- *Lobelia dortmanna* L.
- *Myrica gale* L. (most common shrub at immediate shoreline)

ANIMALS

Porifera (M. C. Old, Hofstra College)
- *Spongilla lacustris* (Linnaeus)
- *Heteromeyenia ryderi* Potts

Rotifera (G. M. Neal, University of Toronto)
- *Polyarthra trigla* Ehrenberg
- *Kellicottia longispina* (Kellicott)
- *Keratella cochlearis* (Gosse)
- *Keratella taurocephala* Ahlstrom
- *Asplanchna priodonta* Gosse
- *Trichocera cylindrica* (Imhof)
- *Ploesoma lenticulare* Herrick
- *Conochilus unicornis* Rousselet

Bryozoa
- *Fredericella* sp.

Hirudinea (M. C. Meyers, University of Maine)
- *Helobdella stagnalis* (Linnaeus)
- *Placobdella* sp.
- *Macrobdella decora* (Say)
- *Erobdellidae*

Crustacea — Cladocera (M. W. Smith)
- *Leptodora kindtii* (Focke)
- *Polyphemus pediculus* (Linné)
- *Holopedium gibberum* Zaddach
- *Diaphanosoma brachyurum* (Liéven)
- *Daphnia dubia* Herrick
- *Daphnia pulex* Leydig
- *Bosmina coregoni* Baird
- *Acantholeberis curvirostris* (O. F. Mueller)
- *Ilyocryptus spenifer* Herrick
- *Graptoleberis testudinaria* (Fischer)
- *Chydorus sphaericus* (O. F. Mueller)

Copepoda (M. W. Smith)
- *Epischura lacustris* Forbes
- *Leptodiaptomus minutus* Lilljeborg
- *Mesocyclops edax* (Forbes)

Amphipoda (C. R. Shoemaker, Smithsonian Institute)
- *Hyalella azteca* (Saussure)

Insecta — Ephemeroptera (F. P. Ide, University of Toronto)
- *Paraleptophlebia debilis* Walker
- *Ephemerella prudentalis* McDunnough
- *Ephemerella bicolor* Clemens
- *Caenis* sp. (near *simulans*)
- *Stenonema frontale* Banks

Odonata (E. M. Walker, University of Toronto)
Argia violacea Hagen
Ischnura verticalis Say
Enallagma civile Hagen
Enallagma borealis Selys
Enallagma sp.
Agrion maculata Beauv.
Ephemeropteron sp.
Didymops transverse Say
Tetragoneuria spinigera Selys
Somatochlora cingulata Selys
Hagenius brevistylus Selys
Gomphus exilis Selys
Boyeria vinosa (Say)
Basiaeschna janata (Say)
Hemiptera (M. W. Smith)
Notonecta sp.
Callicorixa spp.
Neuroptera (M. W. Smith)
Sialis sp.
Coleoptera (W. J. Brown, Department of Agriculture, Ottawa)
Haliplus cribrarius Leconte
Hydroporus undulatus Say
Dubiraphia sp. (near *quadrinata* (Say))
Stenelmis crenata (Say)
Lepidoptera (M. W. Smith)
Nymphula sp.
Diptera (M. W. Smith)
Chaoborus sp.
Ceratopogonidae (Heleidae)
Chironomidae (Tendipedidae)
Acari (Rodger Mitchell, University of Vermont)
Limnochares americana Lundblad
Unionicola crassipes Mueller
Limnesia histronica Wolcott
Limnesia maculata Mueller
Limnesia marshallae Viets
Limnesia anomala Koenike
Limnesia sp.
Arrenurus pseudocylindratus Piersig
Arrenurus acutiformis Marshall
Arrenurus sp.
Libertia sp.
Piona turgidus Wolcott
Mollusca — Gastropoda (J. R. Oughton, University of Guelph)
Amnicola limosa porata (Say)
Helisoma decisum Say
Gyraulus deflectus (Say)
Pelecypoda (H. B. Herrington, Keene, Ont.)
Pisidium adamsi Prime
Pisidium casertanum (Poli)
Pisidium variable Prime
Pisidium ferrugineum Prime
Sphaerium securis Prime
Pisces (see Smith, 1968)
Amphibia (M. W. Smith)
Triturus viridescens viridescens (Rafinesque)
Rana catesbiana Shaw

Fishery and Biology of Atlantic Cod (*Gadus morhua*) off the Southwest Coast of Newfoundland

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PINHORN, ALLENBY T. 1969. Fishery and biology of Atlantic cod (*Gadus morhua*) off the southwest coast of Newfoundland. J. Fish. Res. Bd. Canada 26: 3133–3164.

Data collected from the fishery off the southwest coast of Newfoundland indicated a decrease in the proportions of larger and older cod in ICNAF Division 3Pn in recent years. Changes in total mortality rates in 3Pn and on Burgeo Bank have been attributed to fluctuations in total landings and effort. Decreased growth rates for the younger cod and increased followed by decreased growth for the older cod were attributed to increased food supply superimposed on decreased bottom temperatures. Cod from Burgeo Bank grow faster than those from 3Pn. Sizes caught by various types of inshore boats were similar but larger fish were caught in deeper water, in eastern rather than western localities, and in the latter part of the season. Peak spawning occurs in May. Males were predominant in longline catches and matured at an earlier age and smaller size than females. Fish in the 3Pn area matured earlier and at a smaller size than Burgeo Bank fish. Vertebral averages at different localities in the area were similar but averages have decreased in recent years. Limited data on weights and fecundity are presented. Results are discussed in light of the separation of West Newfoundland and Burgeo Bank stocks.

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INTRODUCTION

DURING January–May of each year there is an intensive fishery for cod off the western portion of the south coast of Newfoundland (Fig. 1). A study of the cod supporting this fishery was initiated in the early 1950's to obtain data on their general biology. Particular emphasis was placed on determining the effects of changes in fishing effort and on delineation of stocks in the area. Samples were collected from experimental longline fishing carried out by the Fisheries Research Board of Canada in 1952, 1953, and 1954 and from the inshore commercial fishing operations during 1956–65. Preliminary accounts of the highlights of these investigations have been reported periodically (Fisheries Research Board of Canada, 1952–54, 1958, 1961, 1963, 1965). Data on the general biology of the cod from this area are presented here and changes in age and size compositions, growth, and mortality are analyzed in the light of changes in the fishery and environment.

MATERIALS AND METHODS

Inshore boats are defined as those under 25 gross tons fishing various inshore gears; longliners are those 25 gross tons and over fishing longlines.

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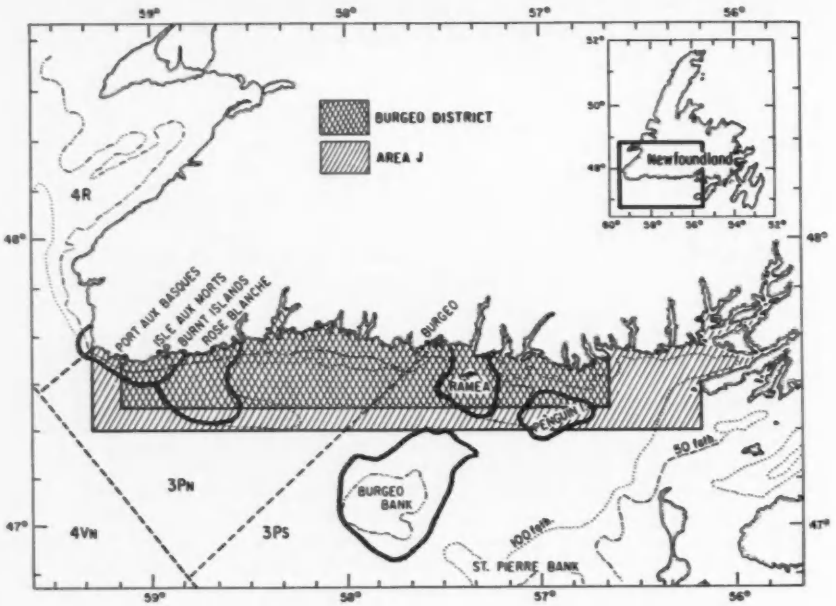

FIG. 1. Location of places and fishing localities referred to in the text.

Statistics from several sources were used in analyses of landings from the fishery. Indications of trends in the fishery by inshore boats were derived from the Annual Reports of the Newfoundland Fisheries Board (1938–48) and from records of the Department of Fisheries and Forestry of Canada in St. John's (after 1948). Since there were no reliable statistics on the fishery by inshore boats in 3Pn before 1957, statistics on landings and men for the larger areas of Burgeo District during 1938–44 and the Canada Department of Fisheries and Forestry Statistical Area J during 1945–48 and 1956–65 were used. These should be indicative of the trends in the smaller 3Pn area (Fig. 1). Statistics for 1949–55 were incomplete and therefore not used. In the 1938–48 period, statistics were available only on salted cod production and numbers of men fishing cod to be salted but since almost all cod landed during this period were processed in this manner, landings per man should give a reasonable estimate of the trends in these years. However, in the 1956–65 period, data on total cod landings and total numbers of cod fishermen were used.

For the offshore fishery by longliner, otter trawler, and pair trawler (25 gross tons and over), figures were obtained from the Statistical Bulletins of the International Commission for the Northwest Atlantic Fisheries.

To assess the overall effect of the otter-trawler fishery, the fishing efforts for Spain and France were converted to standard Portuguese otter-trawler hours by multiplying by an appropriate factor for each country (Hodder, 1965; Wiles, 1967a). Similarly, to assess the overall effect of all gears combined, the effort for each gear was converted to standard otter-trawler hours. The conversion factors used were the slopes of lines drawn by eye through the origin to plots of landings per unit of effort of each country or gear against landings per standard unit of effort (Fig. 2).

In comparing length compositions by vessel type, three classes of vessels fishing longlines are considered: longliners using mechanical gurdies; smaller motor boats hauling gear by mechanical gurdy or by hand; gasoline dories, smaller than either of the above, hauling gear by hand

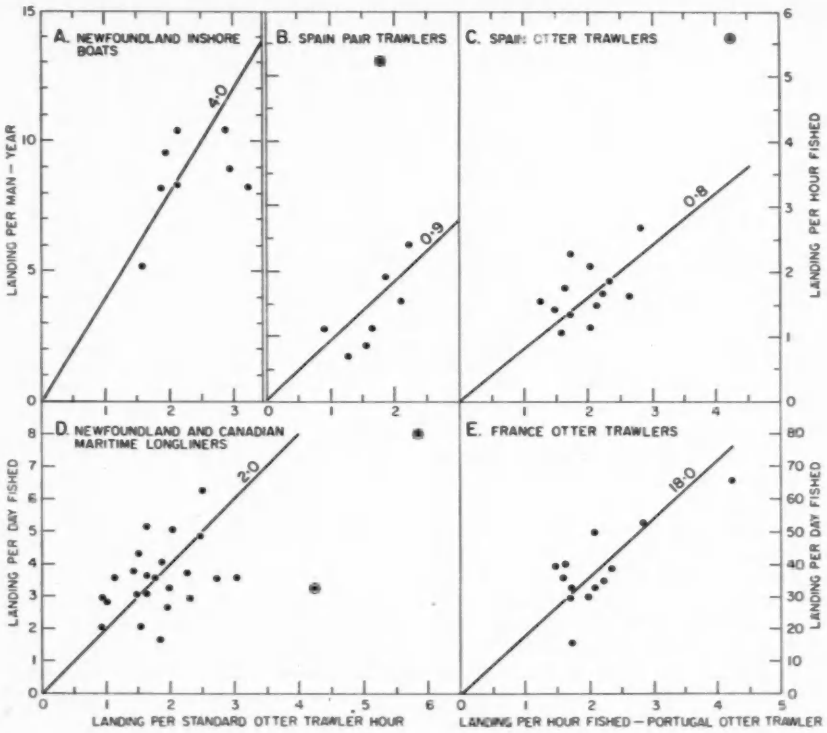

FIG. 2. Cod landings per unit effort in 3Pn for the various countries and gears plotted against landings per standard otter trawler hour (A, B, D) and landings per Portuguese otter trawler hour (C and E) for 1959–66. All scales are in metric tons. Circled points are not included in drawing straight lines.

only. In comparisons by depth, the data were divided into 25-fath depth zones. In comparisons by season, the entire sampling period was divided into quarter monthly periods as follows: in 30-day months the 1st and 3rd weeks contained 7 days and the 2nd and 4th 8 days; in 31-day months the 1st week contained 7 days and the last 3 weeks 8 days; February contained 4 weeks of 7 days duration except in leap years when the final week contained 8 days.

From large numbers of cod measured for length, random samples of 1 in 5, 1 in 10 or 1 in 20 in 1952–63 and a stratified sample in 1965 were selected for otolith collection and detailed biological examination (Table 1). Lengths were to the nearest centimetre measured from the tip of the snout to the midfork of the tail, but were later combined into 3-cm groups for anaiyses. In the earlier years only random samples were collected, but in recent years these were supplemented by fish selected at larger and smaller sizes.

Ages were determined from the otoliths examined mainly by transmitted light (Fleming, 1960), reflected light being used only for determination of edge material. Age samples were adjusted by age–length keys to the total numbers measured. Von Bertalanffy growth curves were fitted to age and length data in each year by the method described by Allen (1966). Mortality rates were estimated from age composition data as described by Ricker (1958). In the age validation study, material reported on by Wiles (MS, 1967b) for 4R and 4S during July–January was used to supplement the data from 3Pn collected during February–April, since the cod inhabiting

TABLE 1. Cod measured and samples collected for age and growth and related biological studies, Newfoundland southwest coast, 1952–65.

Year	Month	No. fish examined					
		Measured	Otoliths	Sex and maturity	Wt	Ovaries	Vertebrae
1952	Feb.	3218	363	363	363	...	320
1953	May	4284	238	238	...	...	197
1954	May	8918	119	119	...	...	108
1956	June–July	1058	101	...	...	...	...
1957	Mar.–Apr.; June–July	15030	1262	541	...	45	...
1958	June–July	2096	199	...	...	...	...
1959	Apr.	6942	643	...	...	...	...
1961	Mar.–Apr.; June–July	5861	1047	...	...	...	...
1963	Mar.–Apr.	11349	1023	490	...	...	452
1965	Feb.–Mar.	3311	229	...	...	...	...

3Pn in winter and spring are part of the West Newfoundland stock that inhabits the Gulf of St. Lawrence in summer and autumn (Templeman, 1962).

In some years observations on sex and maturity and whole and gutted weights were obtained and samples of vertebrae and ovaries were collected. Maturity stages were as described by Fleming (1960). For comparisons of percentage mature at each age, sigmoid curves were fitted to the data by the "LD50" method of Bliss (1935a, b, 1952), as applied by Fleming (1960). For percentage mature at each length the data were combined into 6-cm groups to eliminate some of the variability resulting from small numbers of fish used. Sigmoid curves were not fitted because of the greater irregularities in the data. Weights of individual fish were obtained to a tenth of a pound on a spring balance (1 lb = 0.454 kg). Vertebral counts did not include the urostylar half-vertebra. Numbers of eggs were estimated by a volumetric method using the whirling vessel described by Wiborg (1951) and Pitt (1964).

All landings and landings per unit of effort are expressed in metric tons, round fresh (1 metric ton = 2204.6 lb).

THE FISHERY

GENERAL BACKGROUND OF THE FISHERY

Not until 1959 did all countries report statistics on landings and effort in ICNAF Division 3Pn separately from 3Ps, statistics before that time being reported for the larger Division of 3P only. Thus, except for the Newfoundland inshore fishery, it is impossible to determine accurately the proportions of cod landed by each country and gear in 3Pn before 1959. Large landings were reported by foreign otter trawlers and pair trawlers and by Canadian otter trawlers and Danish seiners on the southern side of Cabot Strait in ICNAF Division 4V from 1953 onwards (Paloheimo and Kohler, 1968), but it is not known whether this occurred on the northern side in 3Pn or not. In any case the Newfoundland inshore boats accounted for over 50% of the landed weight of the cod catch in 1959, whereas in the 1960's only 10–25% was landed by

inshore boats, with otter trawlers and longliners accounting for the remainder (Fig. 3A and Table 2).

The fishery is a seasonal one, extending from January to May with only small amounts being landed in the June–December period (Fig. 3B). The peak of the fishery was in February and March for the longliners in the 1958–66 period, in March for the otter trawlers in the 1959–66 period, and in March and April for inshore boats in the 1957–66 period (Fig. 3B).

Trends in Landings, Effort, and Landings per Unit Effort

Otter trawlers — Landings and effort by otter trawlers in 3Pn increased to a peak in 1961 and then decreased in 1963–66. Landings per hour fished

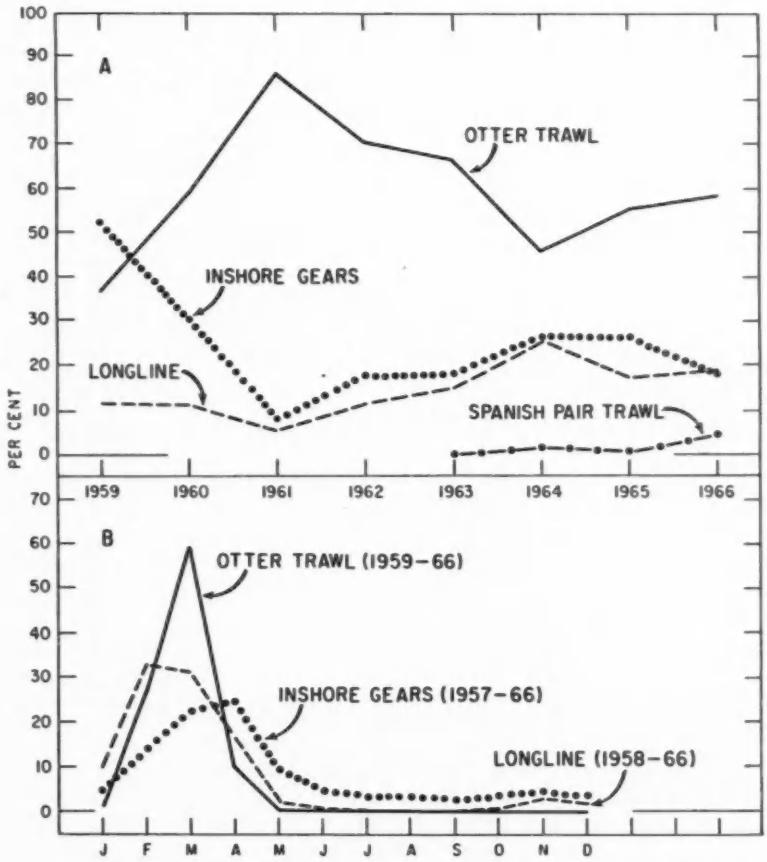

Fig. 3. A, Percentages of cod landed from each type of gear in the 1959–66 period, 3Pn. B, Percentages of cod landed in each month from the three main gears fishing in 3Pn. Percentages are based on average monthly landings for the entire period.

TABLE 2. Landings (metric tons) of cod by country and gear, 3Pn, 1959–66.

	Otter trawl											Pair trawl	Longline	Inshore gears	
Year	Portugal	Spain	France (mainland)	Canada (mainland)	Canada (Nfld.)	USSR	Norway	United Kingdom	France (St. Pierre)	Poland	Iceland	Total	Spain	Canada	Canada (Nfld.)	Total
1959	1,162	59	1,133	...	...	...	...	...	...	...	...	2,354	...	725	3,349	6,428
1960	976	1,428	3,694	...	3	...	..	...	...	...	...	6,101	...	1,137	3,129	10,367
1961	8,282	15,536	8,615	34	...	...	...	...	...	...	...	32,467	15	2,000	3,080	37,562
1962	3,506	9,536	3,807	3	17	...	...	...	...	...	...	16,614	29	2,688	4,245	23,576
1963	4,086	5,764	2,148	64	13	12	1,167	...	...	...	...	13,254	...	2,976	3,613	19,843
1964	1,558	1,485	2,015	...	104	213	...	236	...	...	387	5,998	178	3,387	3,523	13,086
1965	896	1,324	5,206	...	531	1	...	430	196	...	...	8,584	142	2,699	4,122	15,547
1966	543	1,113	3,470	...	1,303	...	...	13	329	9	448	7,228	559	2,363	2,303	12,453
Total	21,009	35,990	30,088	101	1,971	226	1,167	679	525	9	835	92,600	923	17,975	27,364	138,862

fluctuated around 2.5 tons during 1959–63 but then declined to 1.5 tons in 1966 (Fig. 4A).

Longliners — Landings and effort by Canada (Newfoundland) and Canada (Maritimes) longliners increased steadily from 1958 to a peak in 1964 (Fig. 4B). Landings per day fished fluctuated only slightly around 3 tons except for 1961 and 1962 when higher landings per effort were realized.

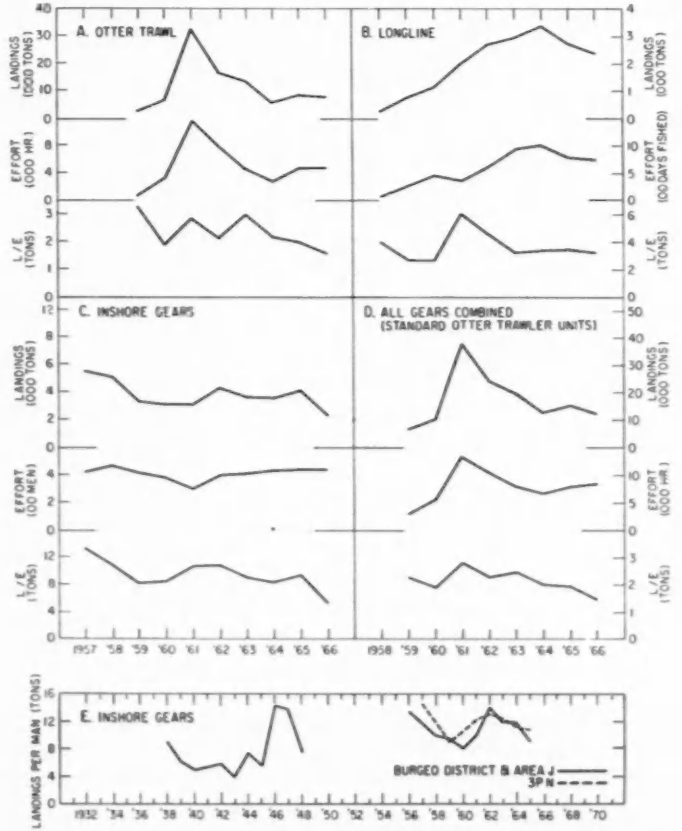

FIG. 4. A–D, Landings, effort, and landings per unit effort for the various gears fishing in 3Pn. E, Long-term landings per unit effort for Burgeo District–Area J.

Inshore boats — Landings, effort, and landings per unit effort by Canada (Newfoundland) inshore boats in 3Pn fluctuated somewhat during 1957–66 but no discernible trends were evident (Fig. 4C).

Landings per man from the larger Burgeo District — Area J remained fairly stable during 1938–48 except for 1946 and 1947 when the landings per

effort were approximately twice the average for the remaining years (Fig. 4E). In the 1956–65 period landings per man in both Area J and 3Pn fluctuated around 11–12 tons with landings per effort being at a maximum in 1956–57 and 1962 and at a minimum in 1959–60 and 1965 (Fig. 4E).

Standardization of landings and effort for all gears — Landings and effort by all gears combined followed trends for otter trawlers closely, increasing to a peak in 1961. Landings per standard hour fluctuated around 2.3 tons during 1959–63, but decreased to 1.5 tons in 1966 (Fig. 4D).

BIOLOGY

Comparisons of Length Compositions

In comparing sizes of fish caught in any fishery, two factors must be considered: the selection of the gear and the spatial and temporal distribution of the fish. In the present study opportunity was offered to compare the effects of type of vessel, depth, locality, and season on the sizes of fish caught by longline gear. The ideal situation would be to compare sizes of fish in 1 year, one variable at a time, keeping all other variables constant. This method was followed when length measurements were sufficient to produce reasonably accurate length distributions in each category, but in some instances categories and even years had to be combined. In spite of this, it is felt that useful comparisons can be made. In depth zones 51–75 fath and 76–100 fath the length-frequency distributions are similar for all types of vessels (Fig. 5). Therefore, in subsequent comparisons in this section, no distinction is made between vessel type. Sizes of fish caught in different depth zones were similar in each year, but there was a tendency in all years for slightly larger fish to be caught in the deeper zones (Fig. 6). Sizes of fish caught in the Isle aux Morts area were considerably smaller than those caught on Burgeo Bank or in the Ramea area (Fig. 7, A–D) but were similar to those caught in the Rose Blanche area (Fig. 7E). Fish from Burgeo Bank and the Penguin Islands area (0.1-cm difference, Fig. 7F) were larger than in the Isle aux Morts-Rose Blanche area (Fig. 7). There was a general increase in average length of fish caught in the Isle aux Morts area as the season progressed in March and April and a pronounced increase in July (Fig. 8). This is also evidenced by the increasing proportion of large (>61 cm) fish in the samples as the season progressed.

Age and Length Distributions

Validation of ageing techniques — Validity studies of techniques for determining ages from otoliths have previously been reported by Fleming (1960), Kohler (1964), Williamson (MS, 1965), May (1965, 1967b), Wiles (MS, 1967d), and Wells (MS, 1968) for various areas around Newfoundland and the Gulf of St. Lawrence.

Although the complete calendar year is not represented for the present data, it is evident that there is only one opaque and one hyaline zone laid down per year (Fig. 9A, B). The deposition of opaque material commences

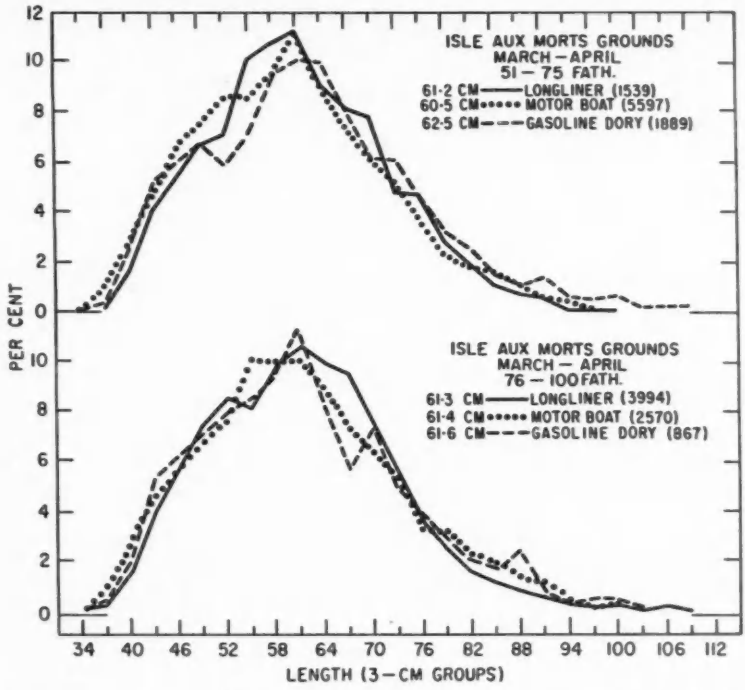
ISLE AUX MORTS GROUNDS
MARCH – APRIL
51 – 75 FATH.
61·2 CM——LONGLINER (1539)
60·5 CM•••••MOTOR BOAT (5597)
62·5 CM– – –GASOLINE DORY (1889)
ISLE AUX MORTS GROUNDS
MARCH – APRIL
76 – 100 FATH.
61·3 CM——LONGLINER (3994)
61·4 CM•••••MOTOR BOAT (2570)
61·6 CM– – –GASOLINE DORY (867)
PER CENT
LENGTH (3–CM GROUPS)
34 40 46 52 58 64 70 76 82 88 94 100 106 112
0 2 4 6 8 10 12

FIG. 5. Length compositions of cod caught by different types of vessels, 1952 + 1957 + 1961. Average lengths are shown for comparison. See text for further explanation of vessel type. Numbers of fish in parentheses.

in July and continues until December with a peak in September. However, in August and September a greater percentage of otoliths of immature than mature fish have opaque material outside of the last hyaline zone, whereas in October and November the reverse is true. During September hyaline material commences to form at the periphery of some otoliths. This material becomes continuous with that formed in the following winter. A greater percentage of immature fish have this hyaline material in the September–November period.

During the peak of the otolith growing season (August–October), opaque material is deposited at the edge earlier in younger than older fish in both immatures and matures (Fig. 9C). Almost all of the otoliths of 1- to 5-year-old immature fish and 4- to 5-year-old mature fish show opaque material at the edge in the August–October period, whereas only about 70–80% of mature and immature fish of 7–8 years and 40% of mature fish of 13–17 years have opaque edges at this time.

Passage of strong and weak year-classes throughout the fishery in successive years is apparent as a further evidence of validation of age-reading

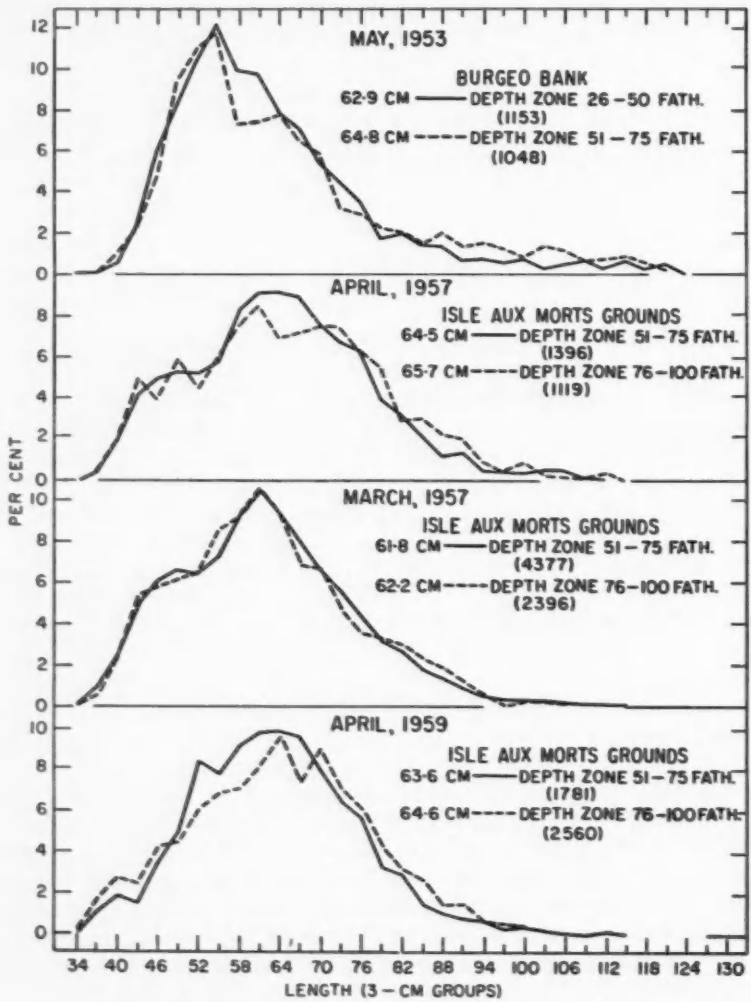
MAY, 1953
BURGEO BANK
62·9 CM ——— DEPTH ZONE 26–50 FATH. (1153)
64·8 CM - - - - DEPTH ZONE 51–75 FATH. (1048)
APRIL, 1957
ISLE AUX MORTS GROUNDS
64·5 CM ——— DEPTH ZONE 51–75 FATH. (1396)
65·7 CM - - - - DEPTH ZONE 76–100 FATH. (1119)
MARCH, 1957
ISLE AUX MORTS GROUNDS
61·8 CM ——— DEPTH ZONE 51–75 FATH. (4377)
62·2 CM - - - - DEPTH ZONE 76–100 FATH. (2396)
APRIL, 1959
ISLE AUX MORTS GROUNDS
63·6 CM ——— DEPTH ZONE 51–75 FATH. (1781)
64·6 CM - - - - DEPTH ZONE 76–100 FATH. (2560)
PER CENT
0 2 4 6 8 10 12
34 40 46 52 58 64 70 76 82 88 94 100 106 112 118 124 130
LENGTH (3–CM GROUPS)

FIG. 6. Length compositions of cod caught in different depth zones. Average lengths are shown for comparison. Numbers of fish in parentheses. All vessel types combined.

from otoliths (Fig. 10). The spring collections are composed mostly of the West Newfoundland cod whereas the summer collections are mostly of the Burgeo Bank cod. In particular the weak 1951 year-class that occurs in 1956 as 5-year-old fish can be followed in successive years until 1965, when it is conspicuous by its absence. In each year the 1951 year-class is less abundant than either of its adjacent year-classes of 1950 or 1952. Similarly, the 1947

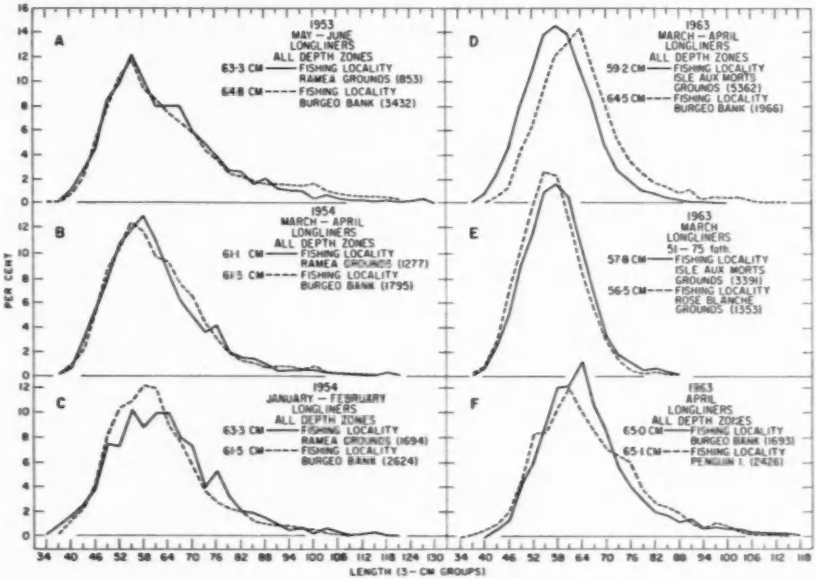

FIG. 7. Length compositions of cod caught in different localities. Average lengths are shown for comparison. Numbers of fish in parentheses.

and 1948 year-classes can be followed through the fishery from 1956 to 1963 and appear in each year more abundant than the adjacent year-classes of 1946 and 1949.

Ages and sizes of fish — Age and length distributions indicate that the longline catches in the 1952–65 period consisted of a wide spectrum of ages and lengths for both 3Pn and Burgeo Bank areas. Ages ranging from 4–5 years to 12–13 years and lengths ranging from 45–50 cm to 80–85 cm were important contributors in the various years (Fig. 10).

In the 1952–59 period the age distributions in 3Pn were characterized by the presence of significant numbers of fish greater than 9 years of age. However, in the 1961–65 period, the proportion of these older fish decreased considerably. This is also obvious in the length frequencies by a decrease in the percentages of larger fish and thus in the average lengths in the 1961–65 period. There is some indication of the same trend for Burgeo Bank samples although it was masked by the predominance of the 1947 year-class in 1953 and 1954 (Fig. 10).

The proportion of older fish caught increased as the season progressed. The proportion of fish over 7 years of age was greater in April than in March and much greater in June–July than in either March or April (Fig. 10).

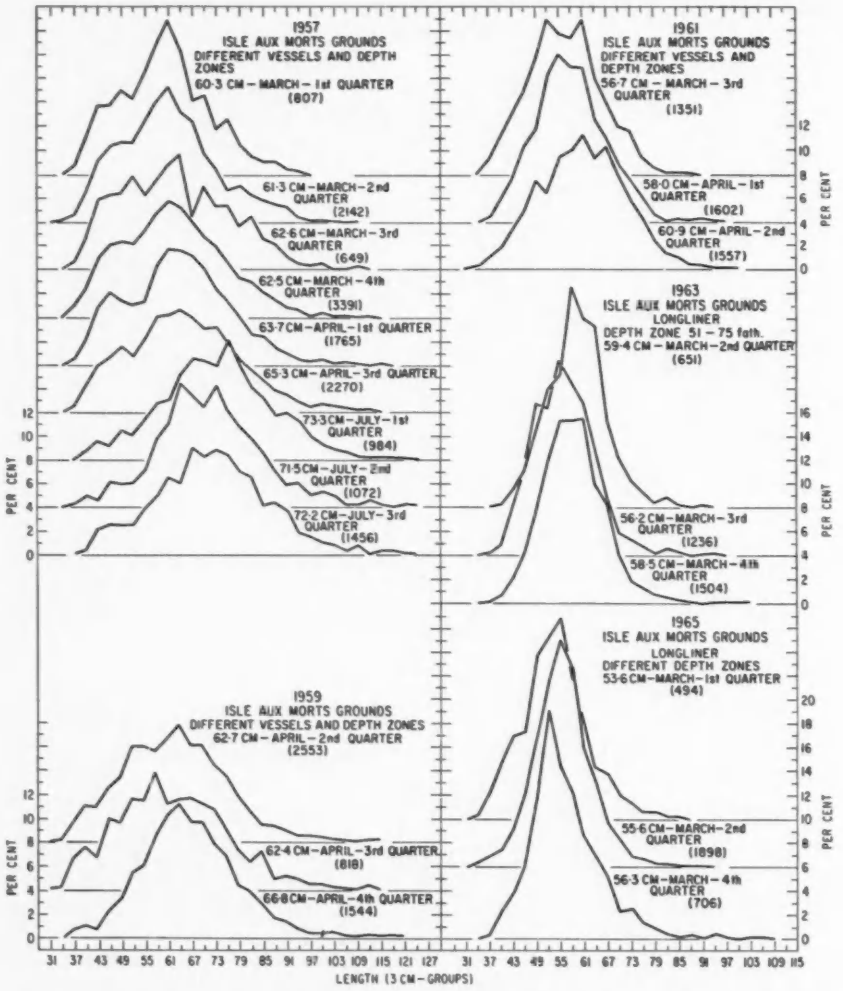
1957
ISLE AUX MORTS GROUNDS
DIFFERENT VESSELS AND DEPTH ZONES
60·3 CM – MARCH – 1st QUARTER (807)
61·3 CM – MARCH – 2nd QUARTER (2142)
62·6 CM – MARCH – 3rd QUARTER (649)
62·5 CM – MARCH – 4th QUARTER (3391)
63·7 CM – APRIL – 1st QUARTER (1765)
65·3 CM – APRIL – 3rd QUARTER (2270)
73·3 CM – JULY – 1st QUARTER (984)
71·5 CM – JULY – 2nd QUARTER (1072)
72·2 CM – JULY – 3rd QUARTER (1456)
1959
ISLE AUX MORTS GROUNDS
DIFFERENT VESSELS AND DEPTH ZONES
62·7 CM – APRIL – 2nd QUARTER (2553)
62·4 CM – APRIL – 3rd QUARTER (818)
66·8 CM – APRIL – 4th QUARTER (1544)
1961
ISLE AUX MORTS GROUNDS
DIFFERENT VESSELS AND DEPTH ZONES
56·7 CM – MARCH – 3rd QUARTER (1351)
58·0 CM – APRIL – 1st QUARTER (1602)
60·9 CM – APRIL – 2nd QUARTER (1557)
1963
ISLE AUX MORTS GROUNDS
LONGLINER
DEPTH ZONE 51 – 75 fath.
59·4 CM – MARCH – 2nd QUARTER (651)
56·2 CM – MARCH – 3rd QUARTER (1236)
58·5 CM – MARCH – 4th QUARTER (1504)
1965
ISLE AUX MORTS GROUNDS
LONGLINER
DIFFERENT DEPTH ZONES
53·6 CM – MARCH – 1st QUARTER (494)
55·6 CM – MARCH – 2nd QUARTER (1898)
56·3 CM – MARCH – 4th QUARTER (706)
PER CENT
LENGTH (3 CM – GROUPS)
31 37 43 49 55 61 67 73 79 85 91 97 103 109 115 121 127

FIG. 8. Length compositions of cod caught during quarter-monthly periods of each year. Average lengths are shown for comparison. Numbers of fish in parentheses. Curves are vertically displaced four percentage units in each year for ease of comparison. Ordinate scale refers to bottom graph in each year.

GROWTH RATES

The growth pattern for cod in 3Pn and on Burgeo Bank can be described by the von Bertalanffy growth equation (Allen, 1966). K-values ranged between 0.09 and 0.20, and L_∞-values ranged between 78.9 and 97.6 cm, except for Burgeo Bank in 19535–4 where L_∞ was 119.3 cm (Fig. 11).

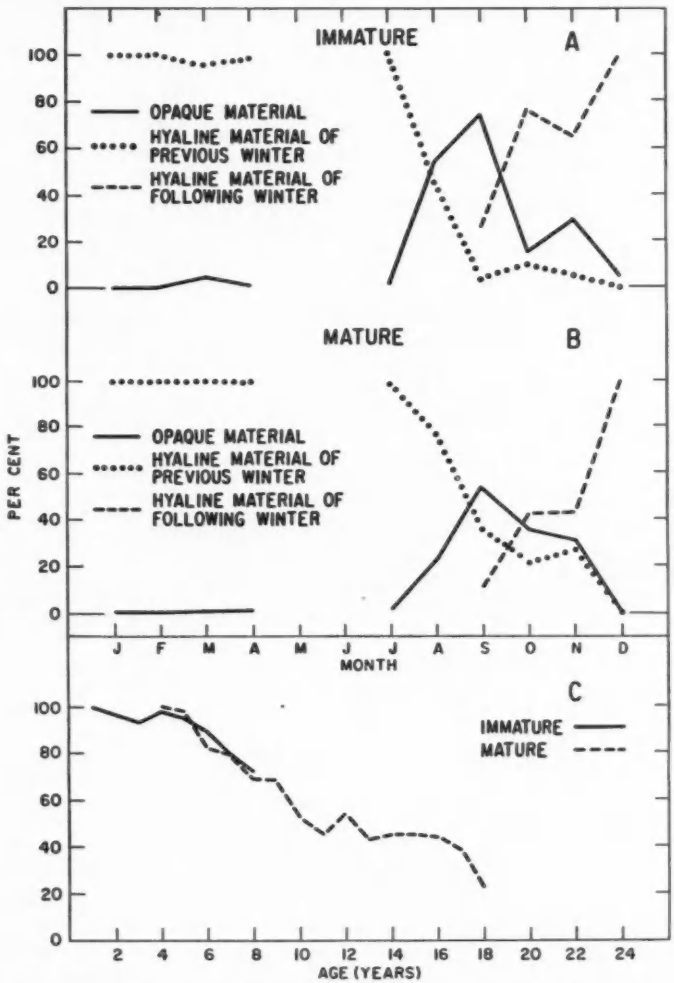

FIG. 9. Otolith growth of West Newfoundland cod stock. A–B, Monthly incidence of opaque and hyaline edge deposits. C, Incidence of opaque edge deposits by age, August–October.

Comparisons of average lengths between years for each age-group in 3Pn indicated a downward trend in average lengths in the 1952–65 period for age-groups 4–8. Age-groups 9–14 exhibited an increase between 1952 and 1957 and a decrease thereafter (Fig. 12A). The only exception was age 11 where the average length increased between 1963 and 1965. Comparisons of fitted von Bertalanffy growth curves for each year indicated similar trends

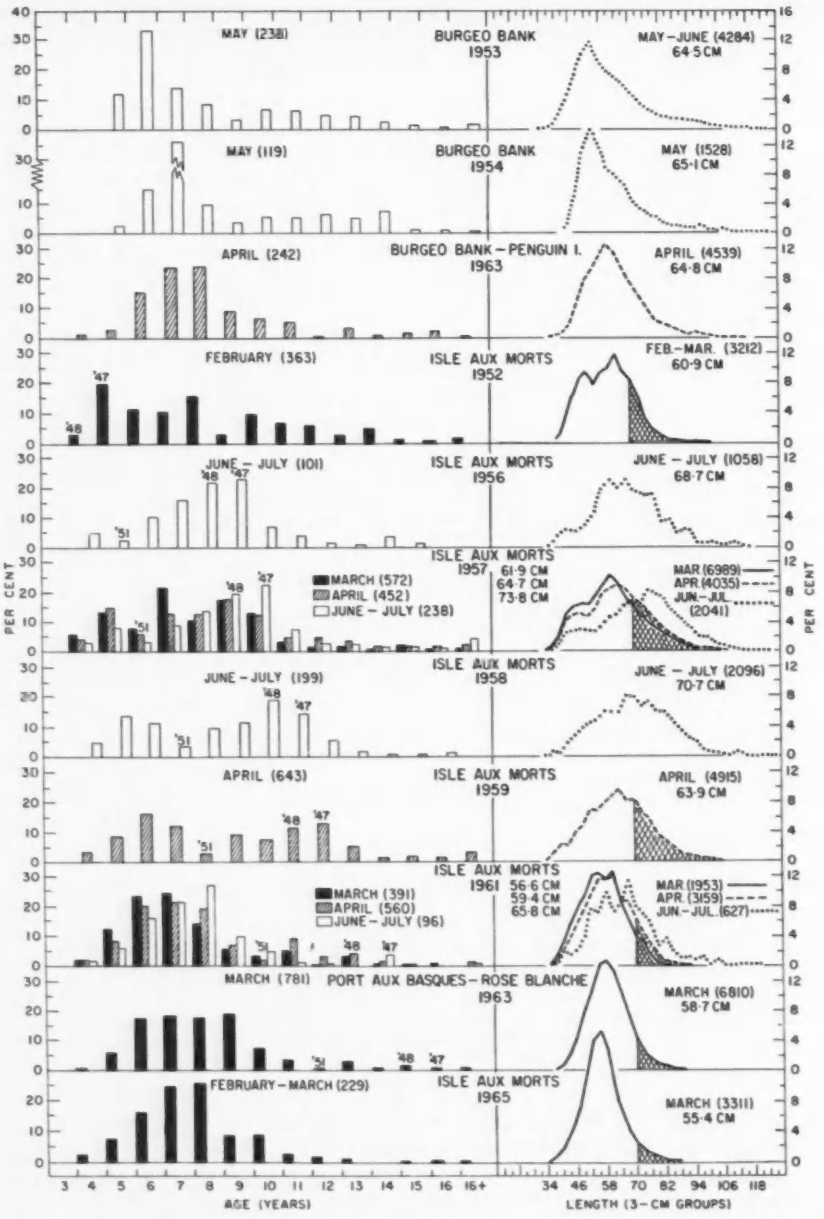

FIG. 10. Age and length distributions of cod caught by inshore boats and longliners in the 1952–65 period. Numbers of fish aged and measured are in parentheses. Average lengths are shown for comparison. Different cross hatching is used to facilitate comparisons of distributions between years during the early part of the fishery (February–March), the latter part of the fishery (April), and after the fishery (May–July).

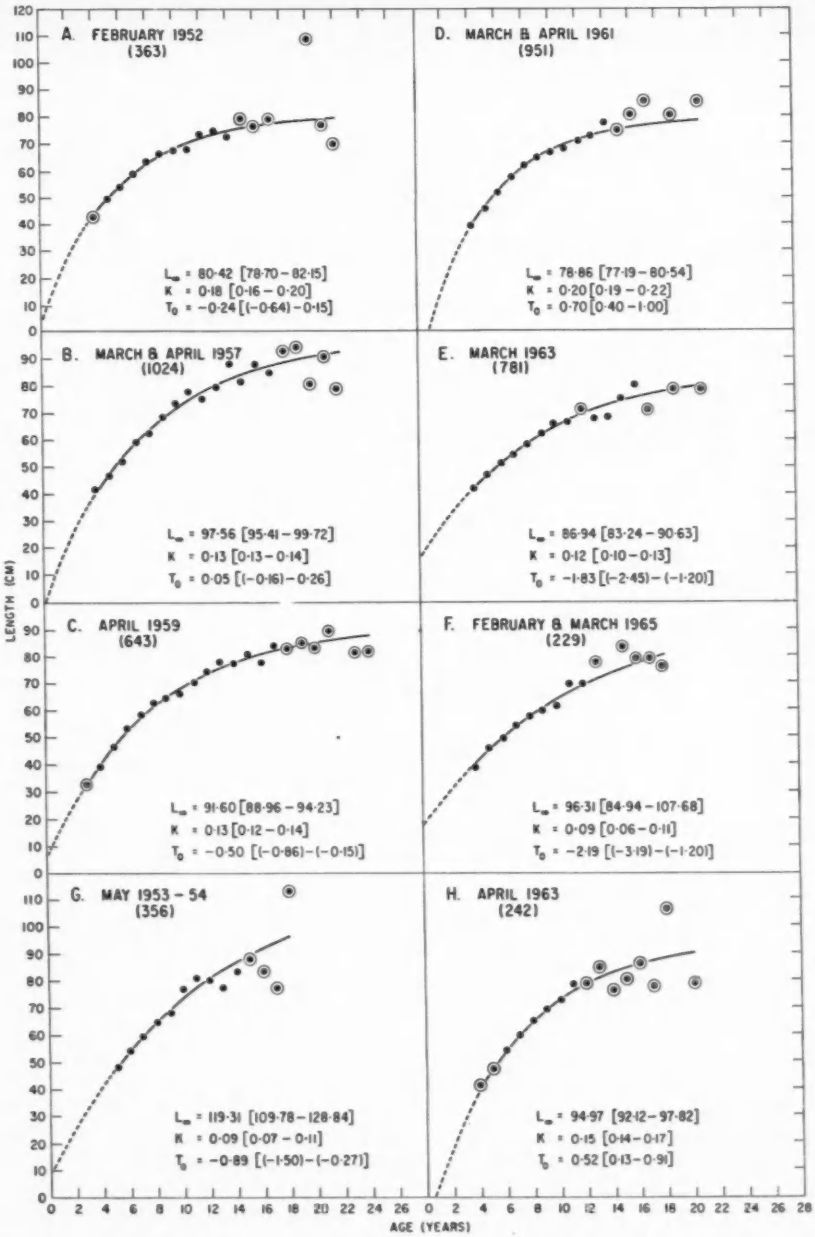

FIG. 11. Von Bertalanffy growth curves fitted to number of cod at each age and length in ICNAF Division 3Pn (A–F) and Burgeo Bank (G–H), longline, 1952–65. Average lengths at each age are plotted for goodness of fit. Solid circles represent averages based on less than 10 fish. The parameters of the growth equation with 99% confidence limits are shown for comparison.

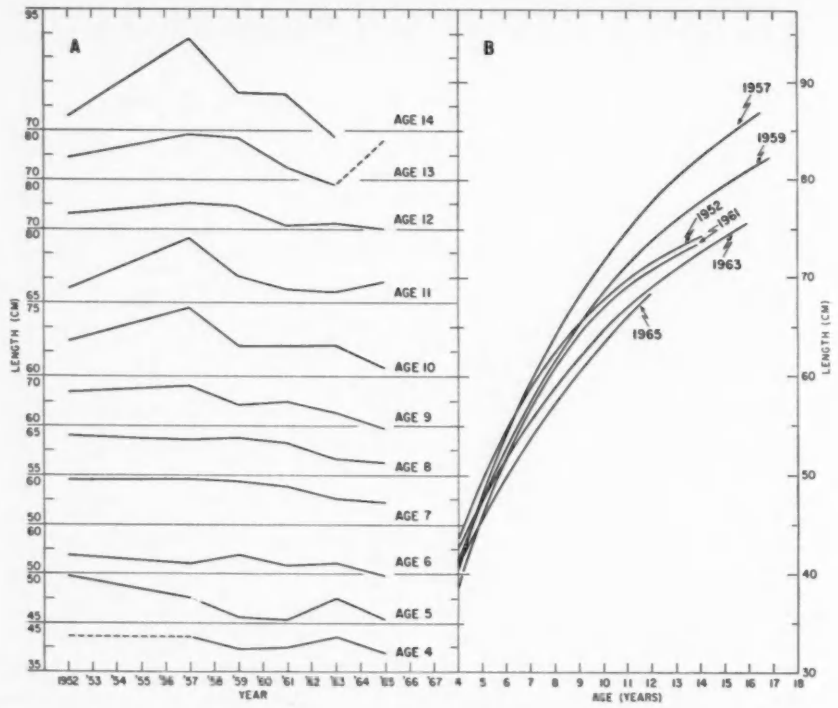

FIG. 12. A, Average lengths at corresponding ages in the 1952–65 period. Dotted lines connect points where one or both are based on less than 10 fish. B, Fitted von Bertalanffy growth curves for each year, 3Pn area, February–April period.

(Fig. 12B). Comparisons on a seasonal basis showed that the average lengths at corresponding ages in March and April were very similar (Fig. 13). However, there were considerable differences in sizes of fish at each age between the March–April and the June–August periods, the average lengths for June–August being 2–3 cm greater than those for March–April for the earlier age-groups and 8–12 cm for the later age-groups.

Von Bertalanffy growth curves of cod in the Burgeo Bank area (Fig. 11G, H) indicated a faster growth rate than those for the 3Pn area (Fig. 11A, E) in corresponding periods especially above age 5.

TOTAL MORTALITY ESTIMATES

Straight line regressions fitted to catch curves derived from age distributions for cod caught in the winter–spring period in 3Pn indicated a change in total mortality rate in the 1952–65 period (Fig. 14A–C). The curve for the 1952–61 period yielded a reasonably straight descending right limb with a total instantaneous mortality rate (Z) of 0.44, annual mortality rate (*a*) of

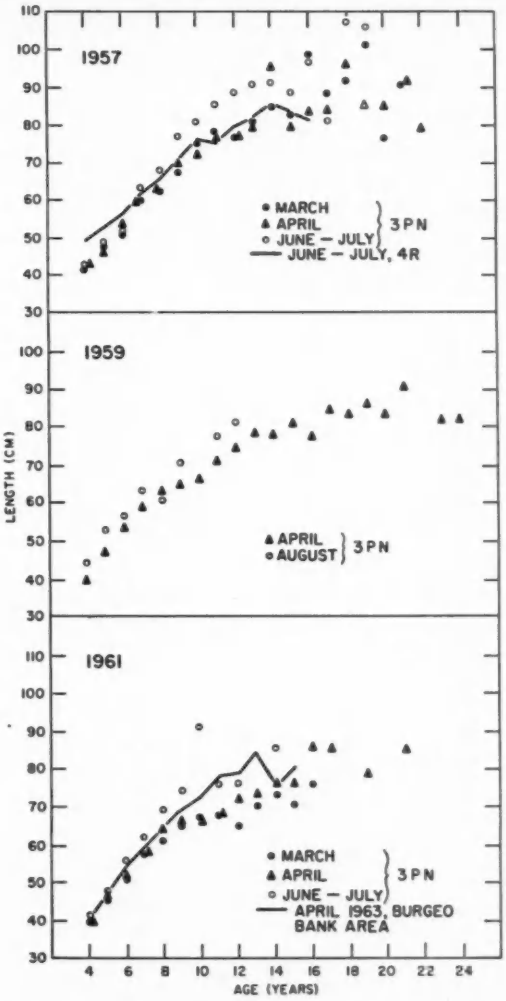

FIG. 13. Average lengths at each age of fish sampled in different months. The 4R curve in 1957 is from Wiles (1967b).

36% (Fig. 14A). However, the catch curve in 1963 for 3Pn indicated a greater mortality rate for the younger ages than for the older (Fig. 14B). The Z for the younger age-groups in 3Pn was higher in 1963 and 1965 than that for 1952–61. The Z for the older age-groups in 1963 was similar to that for 1952–61.

Data for Burgeo Bank cod caught in the spring on Burgeo Bank (1953–54 and 1963) and in the summer in 3Pn (1956–58 and 1961) indicated that the total mortality rate was greater for older than younger age-groups during 1953–54 (Fig. 14D). In 1956–58 the mortality rate was greater than that for the younger age-groups in 1953–54 but not as great as for the older groups

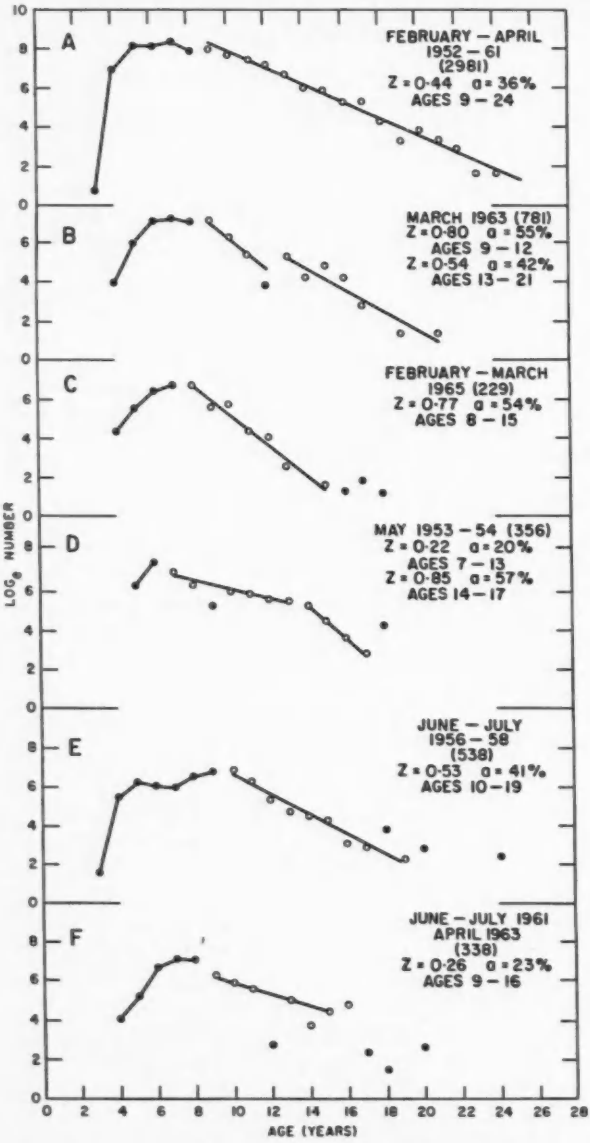

FIG. 14. Catch curves used for total mortality estimates. A–C, West Newfoundland cod; D–F, Burgeo Bank cod. Solid circles represent points not used in the estimation of Z because of incomplete recruitment or variation in recruitment. Numbers of fish in parentheses.

(Fig. 14E). By 1961–63 the rate was again about the same as for the younger age-groups in 1953–54 (Fig. 14F).

Sex and Maturity

Sex ratios indicated that in all years except 1954, a significantly greater percentage of females than males was caught by longline gear (Table 3).

TABLE 3. Percentage of males and females in longline catches of different years with χ^2 test for each one. Asterisk (*) indicates significance at the 1% level.

Year	Males	Females	Total	Males (%)	Females (%)	χ^2
1952	156	207	363	42.98	57.02	7.17*
1953	94	146	240	39.17	60.83	11.27*
1954	66	54	120	55.00	45.00	1.20
1957	227	314	541	41.96	58.04	13.99*
1963	185	305	490	37.76	62.24	29.39*
Total	728	1026	1754	41.51	58.49	50.63*

Tabulation of the various stages of maturity observed indicated that during the February–April period in 3Pn approximately 25% of males and females were immature whereas 70% were in the early stages of maturing for the current spawning period. About 5% showed signs of having spawned in the previous year with very little indication in the females, but some indication in the males, of recovering for the current spawning period. In the Burgeo Bank samples in May approximately 40% of the males and females were immature. About 30% of the males and 20% of the females showed indications of maturing for the current spawning period, whereas 30% of the males and 40% of the females were either in the spawning stage or had completed spawning.

Males were found to mature at an earlier age than females, the age at 50% maturity (M50) being at all times less for males than for females (Fig. 15). Also, both males and females from the Isle aux Morts area were found to mature earlier than those from the Burgeo Bank area. Finally, fish matured at an earlier age in 1952 in the Isle aux Morts area than in 1957. Data for 1963, although available, were not used because some doubt existed as to the validity of the maturity stages determined.

Males matured at a smaller size than females (Fig. 16). Also, fish from the Isle aux Morts area matured at a smaller size than those from the Burgeo Bank area. There was very little difference in the percentages mature at each length for males in 1952 and 1957, although in 1957 they matured a little later than in 1952. For females, fish above about 50 cm matured later in 1957 than 1952, whereas below this length the reverse was true, Again, the 1963 data were not used.

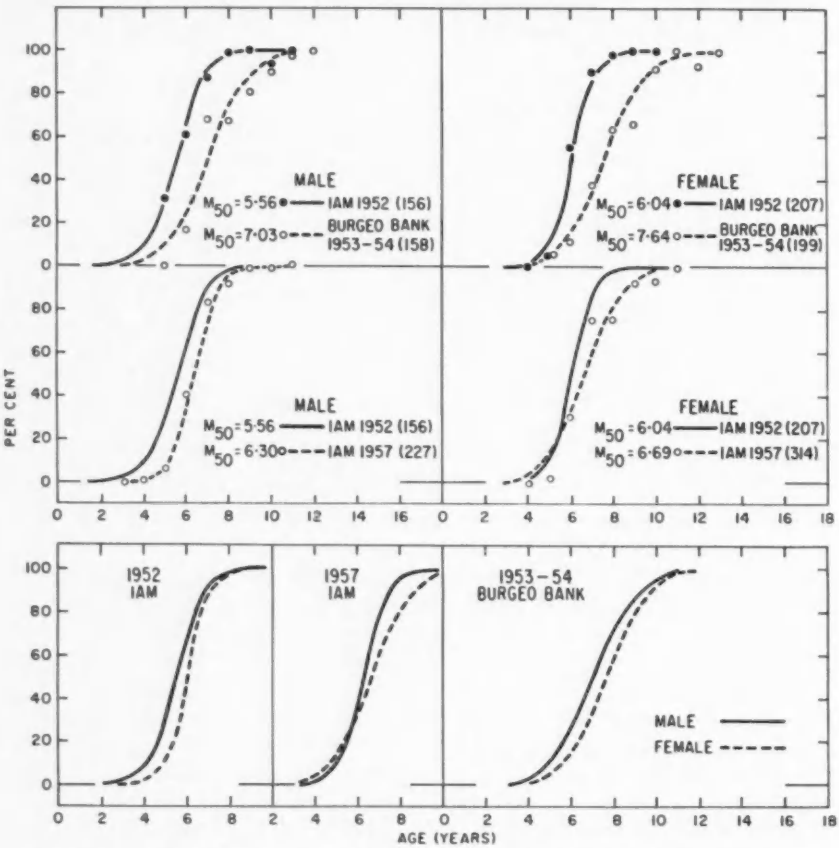

FIG. 15. Percent cod mature at each age, 1952–57. Numbers of fish in parentheses.

LENGTH–WEIGHT

Unweighted exponential curves of the form $Y = CX^a$ fitted to length–weight data indicated a close adherence to the isometric form of growth in weight with length, with the exponents very closely approximating the basic cubic relationship ($a = 3.1$ for round cod and 3.0 for gutted cod) (Fig. 17).

FECUNDITY

A curve of the form $Y = CX^a$ was fitted to the fecundity estimates versus length although variation generally and even within each length was large (Fig. 18). Over this range of data, the fecundity increased at a rate slightly greater than the square of the length (2.18 exponent).

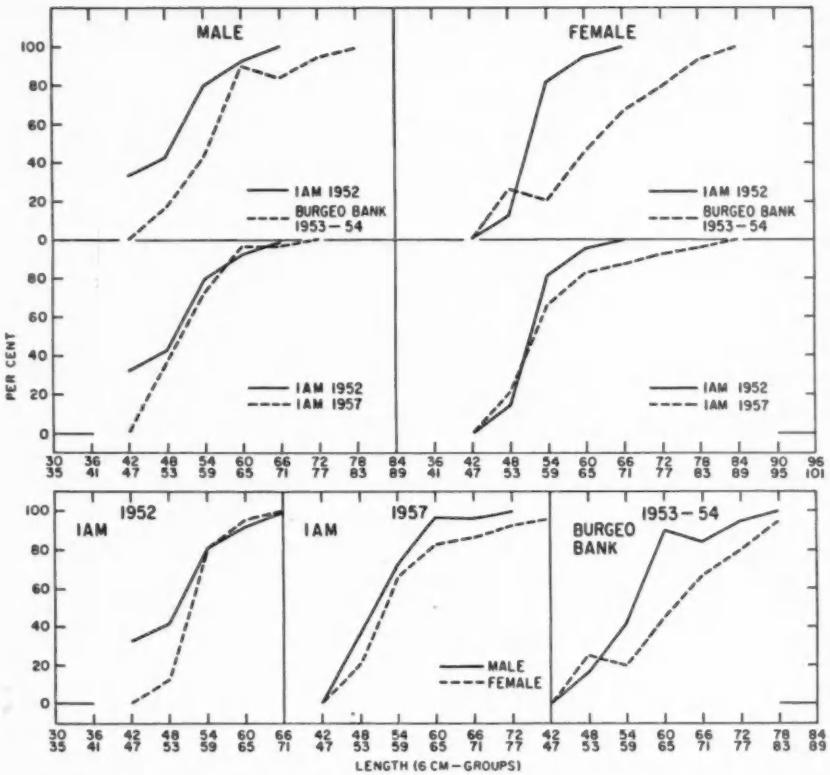

FIG. 16. Percent cod mature at each length interval, 1952–57. See Fig. 15 for numbers of fish in samples.

VERTEBRAL AVERAGES

Tests of significance (*t*-tests) indicated no significant differences in average vertebral numbers among the Port aux Basques–Isle aux Morts area, the Rose Blanche area, and the Burgeo Bank area in either the early or late period, but fish from the Penguin Islands area had a significantly higher vertebral average in the 1963 period than any of the other three areas ($P = 0.015$–<0.001) (Fig. 19).

Comparisons of vertebral averages for the two periods indicated that the average for Isle aux Morts, 1952, was significantly higher than that for either Port aux Basques ($P < 0.001$) or Rose Blanche ($P < 0.005$) in 1963. Also, the averages for Burgeo Bank in 1953 and 1954 were significantly higher than that for Burgeo Bank in 1963 ($P < 0.005$ for 1953; $P = 0.015$ for 1954) (Fig. 19). In fact, the averages in the 1952–54 period were not significantly different from that for the Penguin Islands sample in 1963.

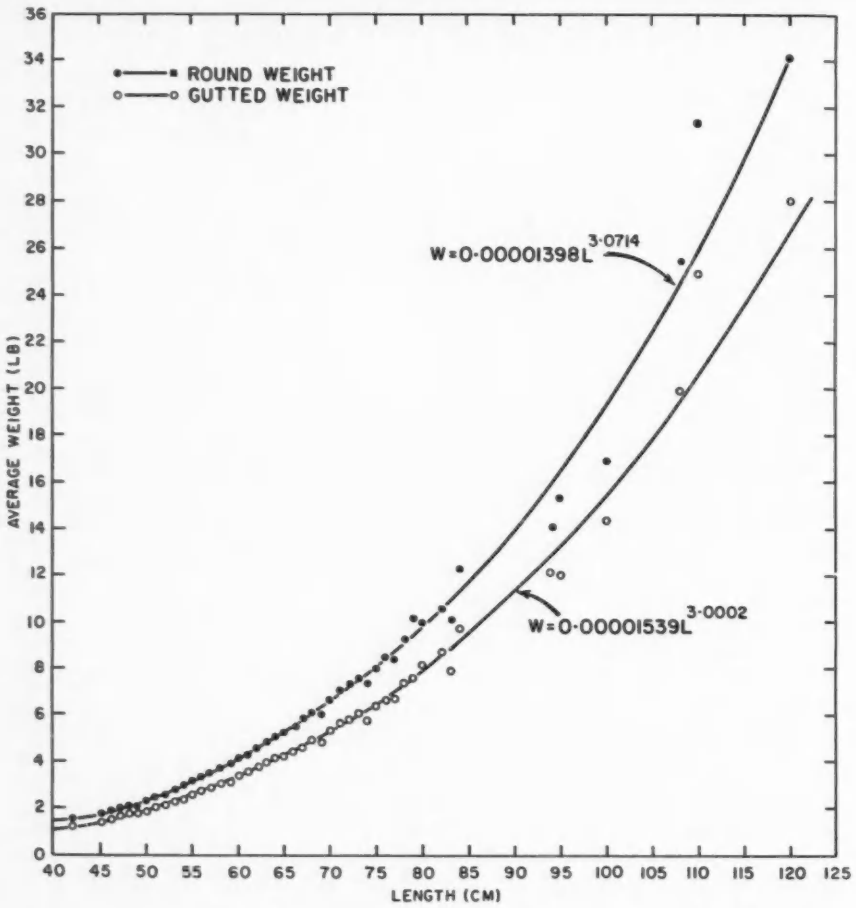

FIG. 17. Average weights of cod at each length with fitted exponential curve, 3Pn, 1952.

DISCUSSION AND CONCLUSIONS

STANDARDIZATION OF EFFORT

Conversion factors used to adjust the effort by the various gears to standard trawler hours were derived from slopes of lines that were at times only approximate fits to the points used (Fig. 2). That for Spanish otter trawl was 0.8, which agrees very well with 0.8 used by Hodder (1965) for Subarea 2 and 3K-3L cod and 0.9 used by Wiles (MS, 1967a) for 4R cod and Wells (MS, 1968) for 3K cod. For French otter trawl (days fished), the factor of 18 seems reasonable since the line drawn through the points is a fairly good fit. Also, assuming a conversion factor of 0.8 on an hourly basis, this means that a

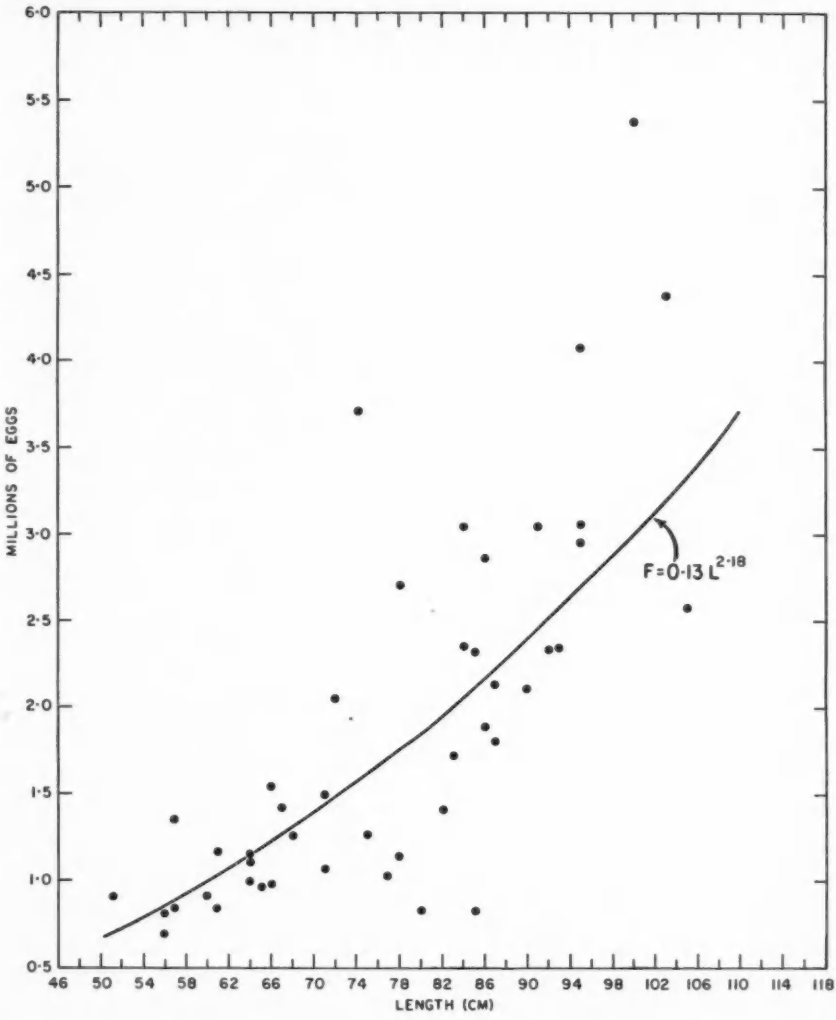

FIG. 18. Scatter diagram of fecundity plotted against length with fitted unweighted exponential curve, 3Pn, 1957.

French otter trawler's fishing day averaged 15 hr. The average for Spain and Portugal in 1959–66 was 12 hr per day fished. The figure of 0.9 for Spanish pair trawlers compares favourably with 0.8 for Spanish otter trawlers. The points for longliners and inshore boats were quite variable but the factor of 2.0 for longliners and 4.0 for inshore boats produced results very similar to those obtained by using either an average conversion factor for the entire

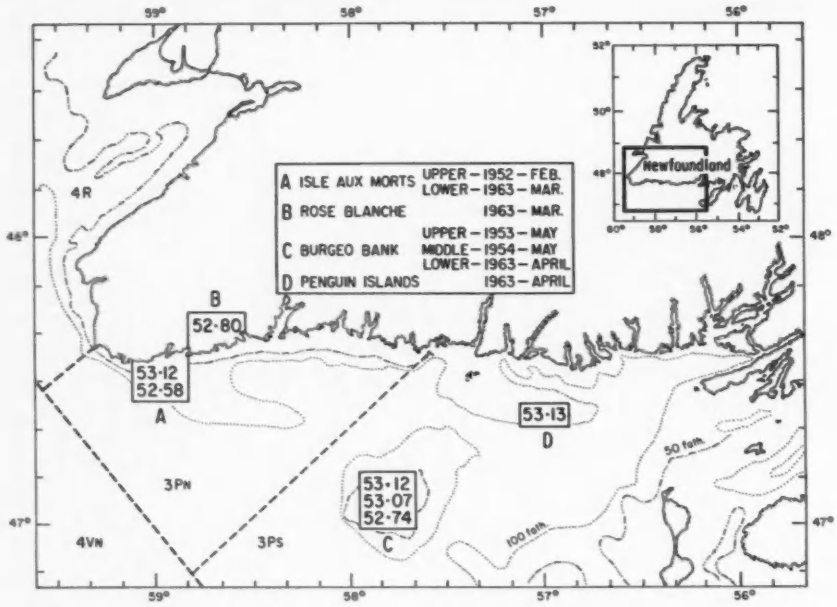

FIG. 19. Locations of vertebral samples and values of vertebral averages, 1952–54 and 1963.

period or by converting on a month-by-month basis (longliners) or a year-by-year basis (inshore boats).In fact, the factor of 4.0 for inshore boats is very similar to that used by Wiles (MS, 1967a) for 4R inshore boats (3.9).

COMPARISONS OF LENGTH COMPOSITIONS

Other authors have suggested an increase in size of cod caught with increase in depth fished similar to that reported in this study for other areas of Newfoundland (Fleming, 1965; Templeman and Fleming, 1956, 1963). Apparently, as the cod become larger (and older) they tend to remain in deeper water and do not usually move into the shallower water areas inhabited by smaller (and younger) fish.

The cod supporting the winter fishery in 3Pn are part of the West Newfoundland stock that moves out of the Gulf of St. Lawrence in late autumn and early winter (Templeman, 1962). They are smaller than the Burgeo Bank cod to the east (Fig. 7) that migrate inshore during the spring and summer and return to Burgeo Bank in the autumn and winter (Templeman, 1962). Consequently, the average size of fish caught in the 3Pn area would be expected to decrease up to the peak of the fishery as these smaller "Gulf" cod move into the area and increase beyond the peak as the smaller cod move out and the larger Burgeo Bank cod move in. Since all of the length measurements

in this study were obtained either at or beyond the peak of the fishery, the average lengths were found to increase as the season progressed.

Age and Length Distributions

A wide range of ages and lengths in longline catches is generally the case, longline gear being more selective for larger and older fish than most of the other gears (Templeman, 1966). Fleming (1965) and Wells (MS, 1968) reported similar results for longline catches in the Newfoundland east coast area.

A decrease in the proportion of larger and older fish in a fishery, such as occurred in 3Pn after 1959, can occur in a particular year because of peculiar hydrographic or other conditions causing differential availability of young and old fish to the gear in question. However, this is not believed to be the explanation in this instance, since the trend continued in 1961, 1963, and 1965. With an increase in landings and effort on a stock of fish, the relative numbers of larger and older fish decrease progressively (Beverton and Holt, 1957; Ricker, 1958). Since an increase in effort did occur after 1959, it is believed that this increase reduced the numbers of older and larger fish in the 3Pn area. Similar conclusions have been reached by Fleming (1965), Wiles (MS, 1967c), May (MS, 1966b, MS, 1968), and Wells (MS, 1968) for cod from other areas of Newfoundland.

Growth Rates

Several authors have found that von Bertalanffy growth curves describe growth patterns of cod for the greater part of its life span in other areas of Newfoundland (May et al., 1965; Williamson, MS, 1965; May, MS, 1966a; Wiles, MS, 1967b; Wells, MS, 1968). However, in some instances the growth rate increases again above a certain age, presumably because of a change in the cod's diet at this age. Only the 1961 growth curve for 3Pn shows any tendency to underestimate the average sizes of the older fish. The remaining curves show only the expected greater variation at these older ages. May et al. (1965) also cited ICNAF Divisions 3Pn and 3N-O as the exceptions to the above pattern of increased growth rate at older ages.

Changes in growth rate similar to those observed in the 3Pn area can result from several causes. They may be density-dependent resulting from changes in abundance of some or all age-groups (May, MS, 1966a). They can be environmentally induced because of changes in environmental factors over a specified period (Hermann and Hansen, 1965). They may result from changes in the quantity or quality of the food supply of the animal or a change in its diet (Kohler, 1964). The latter condition can itself be affected by environmental changes.

May (MS, 1966a) concluded that increased growth in Labrador cod resulted from an increase in effort in recent years and Kohler (1964) also considered this to be a partial explanation of the increase in growth in the southwestern Gulf of St. Lawrence. This is not likely to be the explanation

for the decrease in average size of younger fish in 3Pn since an increase usually occurs with increased effort. Also, since the fishery was probably reasonably stable in the middle 1950's, being almost entirely by inshore gears in 3Pn and since there were no distinct trends in effort in either 4R or 4S during this period (Wiles, MS, 1967a), the increase in size of older fish between 1952 and 1957 was unlikely to have been caused by density-dependent factors.

Of the possible environmental factors affecting growth, temperature is one of the most important and readily available. Positive correlations have been demonstrated, either directly or indirectly, between cod growth and temperature for various areas of the North Atlantic (Hermann and Hansen, 1965; May et al., 1965; May, MS, 1968). During the 1952–65 period, the range of the present study, Lauzier (1967) has indicated a cooling trend of the order of 0.19 C per year for bottom temperatures in ICNAF Division 4R. Therefore, the observed decrease in average length for age-groups 4–8 during this period is attributed to a decline in the temperature of the environment inhabited by these cod during the growing season. In fact, except for the increased growth between 1952 and 1957, the same general trend is evident for age-groups 9–14.

Kohler (1964) attributed changes in growth in ICNAF Division 4T during 1950–59 to the greatly increased food supply resulting from the abundance of dead and dying herring in the Gulf of St. Lawrence. Sindermann (1958) indicates that these dead herring were also abundant in 4R. Although analyses of food contents of cod from either 4RS or 3Pn are not available, for this period, it is likely that cod were feeding heavily on these herring, since they are important food items in stomachs of cod over 50 cm and especially over 70 cm in length (Powles, 1958). Therefore, the increased growth between 1952 and 1957 in age-groups above 8 years (average length 60 cm) is attributed to increased food supply in the Gulf of St. Lawrence at this time. Similar trends in average length between 1953, 1955, and 1963 are shown by Wiles (MS, 1967b, fig. 2) although their significance is not noted by the author.

The picture of growth for this stock of cod in the 1952–65 period, therefore, is one of decreasing growth caused by a decline in water temperatures throughout the period with an interruption in this downward trend for the older age-groups in 1955–57 attributed to a suddenly increased food supply.

Wiles (MS, 1967b) observed that for Divisions 4R and 4S "commencing in 1961 or 1962, increased growth occurred in cod aged 10 and 11 years, to be followed by increased growth at all ages in 1966." This, he suggests, may be related to increased fishing in the area in recent years. Although the 3Pn cod studied in the present paper are believed to be of the same stock as those reported on by Wiles (MS, 1967b), there was no evidence of this increase in growth up to 1965, but rather a general decrease in average size. Whether growth increased in 3Pn after 1965 is not known.

The differences observed in the average lengths of cod caught in March–April and June–August were greater than would be expected on the basis of the growth expected to take place between the two periods. The Burgeo

Bank fish, which inhabit the 3Pn area in summer, were found to grow faster than the migratory west coast stock inhabiting the 3Pn area in winter and spring (Fig. 11). Therefore, the apparent excessive amount of growth between March–April and June–August was because in June–August the faster growing Burgeo Bank fish were sampled, not the west coast stock. The average lengths of cod caught in 4R during June–July 1957 were close to the average lengths in 3Pn during March–April, whereas the cod caught in 3Pn in June–July 1961 were close in average length to those caught on Burgeo Bank in April 1963 (Fig. 13). The differences between the two curves in each instance are within the limits to be expected on the basis of the growth taking place between the two periods.

Total Mortality Estimates

The straight descending right limb of the catch curve for 3Pn in the 1952–61 period is typical of a fishery in which the landings and effort have not changed significantly during the period (Ricker, 1958). This supports the assumption that the fishery before 1959 was reasonably stable, the major part of it probably being carried on by inshore boats whose landings and effort remained reasonably stable, as was the case in the 1957–66 period.

Concave catch curves of the type observed for 3Pn in 1963 and 1965 are typical of a fishery in which effort has increased and become stabilized at some higher level (Ricker, 1958). The slope of the portion of the curve for the younger age-groups represents the current total mortality rate and the slope for the older age-groups represents the mortality prevailing in the previous period of lower effort. In 1963, 2 years after the increased effort, Z had increased significantly for age-groups 9–12, whereas Z for age-groups 13–21 increased only slightly. In 1965, 4 years after the increase, Z for ages 8–15 was very close to the previous level in 1963 for ages 9–12. These changes are attributed to the increased effort in the 3Pn fishery in recent years. Williamson (MS, 1965), May (MS, 1966b, MS, 1968), Wiles (MS, 1967c), and Wells (MS, 1968) reached similar conclusions for cod in other areas of Newfoundland.

The Z for 1952–61 (0.44) in the present study is very similar to that reported by Wiles (MS, 1967c) for cod taken by small-meshed otter trawl in the 1947–61 period in 4R and 4S (0.39). The values for 1963 and 1965 for the younger age-groups (0.80 and 0.77 respectively) are somewhat higher than that observed by Wiles for otter-trawl caught cod in 4R and 4S in 1962–66 (0.65). The Z-values for longline caught cod in 4R and 4S (Wiles, MS, 1967c) for 1953–64 (0.18 for ages 8–16 and 0.50 for ages 16–22) and that for the 1966 season (0.22) do not agree with the picture presented here for 3Pn cod. No explanation of these differences for the same cod stock caught by the same type of gear is forthcoming at present.

Although no figures for actual landings and effort are available for Burgeo Bank separately, it is known from the general history of the southwest coast fishery that there was a large fleet of jackboats, mainly less than 50 gross

tons, fishing longlines in the area during the 1940's and these fished to a great extent on Burgeo Bank. Also, the banking vessels that pursued the salt cod fishery on the Grand Bank would make several trips during the spring on Burgeo Bank. This fishery dropped off drastically during the late 1940's and early 1950's with the advent of otter trawling in the area. This fairly intensive fishery on Burgeo Bank during the 1940's probably accounts for the increased mortality rate at the time, whereas the decline of this fishery during the late 1940's and early 1950's could account for the decrease in mortality rate during 1953–54. With the decline of the jackboat and banking vessel fishery, the longliner and otter-trawler fishery commenced in the early 1950's but it is not known how rapidly these fisheries increased in this area. By 1959 they accounted for almost 50% of the landings in 3Pn but to what extent they fished on Burgeo Bank is not known. It is likely that the longliners fished there during the middle 1950's and possibly also the otter trawlers and this may have accounted for the increased mortality rate at this time. It is also possible that fishing decreased somewhat in the late 1950's and early 1960's as catch per unit effort declined, thus resulting in lower mortality rates.

Sex and Maturity

Rollefsen (1953) also found a predominance of females in spawning cod caught by longlines in the Lofoten area, whereas those caught by gillnets were predominantly males. He explains this on the basis of the males being more active than females at spawning time and thus being more readily caught by gillnets. The females, being less active, would tend to be caught more readily by longlines. The same reasoning based on differential behaviour of sexes at or immediately before spawning time may explain the 3:2 ratio in the present instance.

No clear indication of the peak spawning season can be derived from the analyses of maturity stages but it must be sometime after April. Wiles and May (1968) found that cod caught in the northern Gulf of St. Lawrence in June were almost all in the post-spawning stage indicating that peak spawning had taken place sometime before June. Peak spawning for this stock must therefore be in May, with some spawning possibly occurring in April and June. This is similar to the cod on St. Pierre Bank immediately to the east of 3Pn (Fig. 1), where peak spawning is during the last half of May and early June (Templeman, 1962) and is somewhat earlier than the cod in the south-western Gulf of St. Lawrence whose peak spawning period is in late June and early July (Powles, 1958). The peak spawning season for cod on Burgeo Bank is in May with possibly some spawning taking place in April and June.

The faster growing fish from Burgeo Bank matured at a later age and larger size than those in the 3Pn area. This is in general agreement with results found by Fleming (1960) for the Newfoundland area generally and agrees with the statement of Alm (1959) that age at maturity "is usually higher in large-sized and often fast-growing forms". Cod in 1957 generally matured at a

later age and larger size than cod in 1952. This difference is also probably because of the increased growth rate in 1957 noted above.

Male cod matured at an earlier age and smaller size than female cod (Fig. 15 and 16). This is generally the case with many species of fish and has been reported previously for cod by Powles (1958), Fleming (1960), Williamson (MS, 1965), May (MS, 1966c), and Wells (MS, 1968).

Fecundity

Fecundity estimates for cod in the Newfoundland area have previously been reported by May (1967a) and Postolaky (1967) and for the southwestern Gulf of St. Lawrence by Powles (1958). May (1967a) fitted an exponential curve to the data with an exponent of 3.42, whereas Powles (1958) fitted a curve with an exponent of 4.64. Postolaky (1967) fitted a straight line to his data. In the present study a curve with an exponent of 2.2 was fitted to the data. This is lower than those reported by Powles (1958) and May (1967a) for both the western and eastern Atlantic. This is believed to be because the narrow range of the data does not permit a curve to be fitted to correctly represent the entire length range of the fish.

Vertebral Averages

In using vertebral averages in stock delineation, differences in averages among areas indicate that different stocks of fish probably inhabit the areas in question. However, similarities of vertebral averages do not necessarily indicate that a homogeneous stock of fish inhabits the areas in question, since the fish could have spawned and the eggs developed and hatched in different areas inhabited by different stocks but with similar sea surface temperatures. It has been shown that the number of vertebrae in fish is determined during the egg or egg and early larval stages of development and that temperature plays an important part (Gabriel, 1944; Tåning, 1944, 1952; Dannevig, 1950; Lindsey, 1954; Molander and Molander-Swedmark, 1957; Seymour, 1959). Templeman and Pitt (1961) summarize the pertinent literature on the relation of meristic characters to the environment. Thus, the similarity of vertebral averages between the 3Pn area and Burgeo Bank does not necessarily indicate a single stock inhabiting these areas.

Lauzier (1967) reports a warming trend in sea surface temperatures in the southwestern Gulf of St. Lawrence between the early 1940's and the middle and late 1950's. Since it has been shown that temperature and vertebral numbers are inversely related (Rounsefell and Dahlgren, 1932; Tester, 1937; McHugh, 1951; Tåning, 1944, 1952; Gabriel, 1944; Dannevig, 1950), the decrease in vertebral numbers in recent years is probably a result of an increase in surface temperatures. Wells (MS, 1968) found a similar decrease for 3K cod which he attributed to an increase in temperature.

Delineation of Stocks

From a comparison of the fishery in the 3Pn area during winter and summer, it is evident that the cod that inhabit the 3Pn area in winter are predomi-

nantly fish that migrate into the area from the Gulf of St. Lawrence. Results presented in this paper indicate these cod are of a separate stock than those inhabiting the Burgeo Bank area. The cod in the Burgeo Bank area are larger than those in the 3Pn area in winter and spring. They also grow faster and attain maturity at a later age and larger size. Also, the periods of increase in total mortality rate and decrease in the proportion of older fish consequent on increase in fishing effort did not coincide in the 3Pn and Burgeo Bank samples. As pointed out above the similarity of vertebral averages between the two groups of fish does not necessarily indicate that they are of the same stock.

After the cod inhabiting the 3Pn area in winter have moved back into the Gulf, a group of large size cod can still be found in the 3Pn area in summer. Whether these belong to a resident stock that remains in 3Pn all year, or are fish of the West Newfoundland stock that ceases to migrate back into the Gulf as they become older, or are all fish of the Burgeo Bank stock that migrates to the coast in summer (Templeman, 1962) is not known at present. Samples from all three areas during the summer would be necessary to determine this.

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Marine Bacteria and Other Heterotrophs as Food for Zooplankton in the Strait of Georgia during the Winter

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Seki, H., and Owen D. Kennedy. Marine bacteria and other heterotrophs as food for zooplankton in the Strait of Georgia during the winter. J. Fish. Res. Bd. Canada 26: 3165–3173.

Microbiological investigation was carried out in the waters of the Strait of Georgia during the winter to study the occurrence of heterotrophic microorganisms in relation to other particulate organic materials, including plankton and detritus. High microbial activity was measured in the euphotic zone, where marine bacteria and allied microorganisms were chiefly found on the particulate matter having diameter less than 25 μ. Their standing crop was estimated by different methods to be between 40 and 3000 mg C/m^3 and some of this was consumed by the zooplankton, which were found to have concentrated the bacteria by a factor of around 10^5. Only the highest levels of microbial production were estimated to be sufficient for the growth of zooplankton and generally the bacterial activity was only sufficient to support a subsistence level of life for marine copepods in the Strait of Georgia.

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INTRODUCTION

From previous reports (Jones and Jannasch, 1956; Riley, 1963), it has been shown that most of the biomass of microorganisms is adsorbed upon particulate matter in the sea, or associated in some form of aggregates. Microorganisms utilize not only the nutrients of the substrata but also the beneficial effects of solid surfaces to retard losses of cellular material by diffusion. An ecological microcosm is often observed in such aggregates, which may include microfauna as well as microflora. Within the microcosm, not only the turnover of nutrients but also the food cycle may proceed efficiently. The metabolism of the ecosystem within the microcosm may be regarded, therefore, as being completely different from that in the ecosystem of an entire water mass.

The importance of heterotrophic microorganisms as food for marine animals has been discussed in a number of earlier reports (Seki, 1964, 1969; Seki et al., 1968). Microscopic observations show that most of the microorganisms attendant with the zooplankton exist in the digestive tract, although some of them are attached on the exoskeleton of zooplankton (Seki, 1966), and others may be inside the tissues (Stewart et al., 1966). Moreover, some kinds of zooplankton can be shown to grow on a bacterial diet. These results suggest that microorganisms are significant as food materials for zooplankton in the sea.

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The biological oceanography of the Strait of Georgia has been examined for 3 years (Bishop et al., MS, 1966; Fulton et al., MS, 1967, and MS, 1968; Stephens et al., MS, 1969). The results indicate that in autumn and winter primary productivity is low and the standing crops of particulate carbon and nitrogen in the sea are at a minimum. In spite of this the number of zooplankton nauplii in the water during the winter are often between 1 and 10 per liter. Therefore, the role of heterotrophic microorganisms may be especially important in the cycle of nutrients and in the food chain during these periods. The purpose of this study was to examine the role of bacteria and other heterotrophs in terms of biomass and growth rates during the winter months to determine if this form of production could sustain the growth of zooplankton that are known to reproduce at this time.

MATERIALS AND METHODS

The sampling stations coincided with locations where physical, chemical, and biological data collections had been made previously in the Strait of Georgia. Stations 1, 7, and DB (Departure Bay) were chosen for the microbiological investigations among these routine sampling stations since they represented three types of environment (viz., deep mixed layer, shallow mixed layer, and a rocky bay). The general characteristics of the stations have been discussed by Waldichuk (1957), Parsons et al. (1969a and b), and LeBrasseur et al. (1969). Positions of the sampling stations are as shown in Fig. 1.

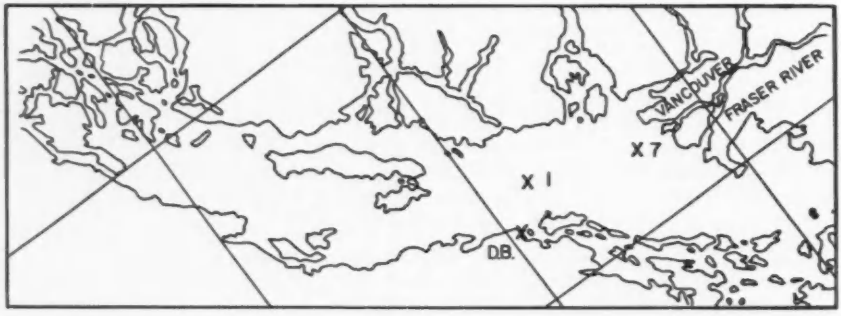

FIG. 1. Positions of sampling stations: station 1 (49°18′N, 123°51.5′W), station 7 (49°10′N, 123°24′W), and station DB (49°12.63′N, 123°57.28′W).

Seawater samples were collected aseptically by Cobet sterile water samplers from depths of 2, 5, 10, 15, and 20 m. Fractions of particulate matter of different sizes were collected in vertical hauls from 20 m with plankton nets of 25, 200, and 350 μ mesh respectively. All plankton hauls were taken with $\frac{1}{4}$ m² POG modified Hensen nets, except the 25-μ samples that were taken in a 26-cm diam cone-shaped net. The nets were hauled at 1 m/sec. Each net was carefully washed by hauling up and down several times between the surface and 20 m, immediately before it was used for sampling. The marine sediments were collected with a Phleger corer. Each undisturbed uppermost layer of water–mud mixture on the sediment was carefully taken into a sterile syringe for microbiological analysis.

A few hundred milliliters of each plankton sample were measured precisely. After the 1-ml sample was taken for the microbiological analysis, the rest was used for the quantitative and

qualitative estimation of plankton biomass, and for the measurement of chlorophyll *a*. Chlorophyll *a* was determined by the method of Strickland and Parsons (1965).

Each plankton sample was filtered on to a 5-μ filter and then washed carefully with autoclaved sea water. The sample on the filter was then washed off into sterile sea water. The mixture was crushed and homogenized in a sterilized blender.

Direct counts were made for total bacteria (University of Tokyo, 1958). Bacteria in sea water, or homogenized plankton samples, were aseptically collected on HA Millipore filters by filtration. The inoculated filters were placed on nutrient agar Medium 2216 (ZoBell, 1941) and were incubated at 15 C for 14 days before colonies of heterotrophic bacteria were counted. Yeasts were counted by the method of Seki and Fulton (1969).

Glucose uptake by microorganisms in samples was measured by the method described in Seki et al. (1969). When the rate of uptake was measured for the samples from depths deeper than 200 m, a correction for the effect of hydrostatic pressure was made according to results of Seki and Robinson (1969). All the microbiological treatments were finished within half an hour of sample collection and, except where especially mentioned, all the results have been expressed as the microbial biomass, or activity, in a water column of 1 m^2, from surface to 20 m depth.

The plankton samples were preserved in 4% formalin, buffered with Hexamine, and examined later in the laboratory. In each sample the animals were counted, measured, and identified to species where possible.

The biomass of phytoplankton was calculated from the relationship (Parsons et al., 1969b):

$$\text{phytoplankton carbon } (\mu\text{g/liter}) = 60 \times \text{chlorophyll } a \ (\mu\text{g/liter}). \quad (1)$$

RESULTS

Microbial Distribution in Sea Water

The depth distribution of microorganisms in the sea water at station 1 is shown in Fig. 2. The microbial population and activity in the sea water were high in the euphotic zone, that is in water less than 20 m in depth. Large concentrations of microorganisms with high activity were also observed in the very thin uppermost layer of marine sediments.

This distribution was common throughout the wintertime. For example, Fig. 3 shows the distribution of heterotrophic bacteria in the sea (station 1) observed every 2 weeks during the winter. Regression analysis of heterotrophic

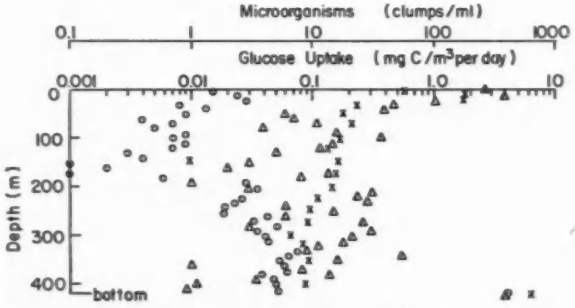

FIG. 2. Vertical distribution of microorganisms and microbial uptake of glucose at station 1 on January 30, 1969. △ = heterotrophic bacteria; ○ = yeasts; × = glucose uptake by microorganisms.

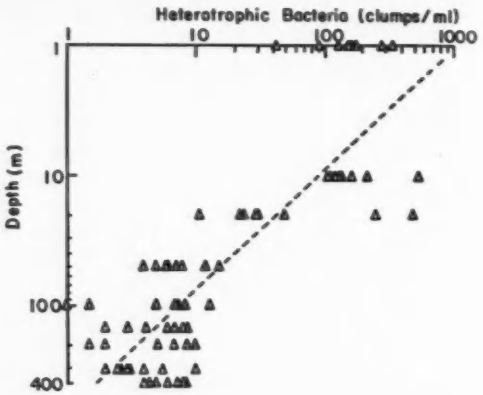

FIG. 3. Heterotrophic bacteria in sea water at station 1 during the winter of 1968–69. Collections of the samples were made at some time in every second week.

bacteria and depth indicates that there was a highly significant linear relationship between the logarithm of the number of organisms versus the logarithm of the depth, i.e., $F_0 = 38.3^{**}$ and $F(1, 70; 0.01) = 7.2$. The regression line was determined to be

$$y = -0.93\ x + 2.8 \qquad (2)$$

where y = logarithm of seawater depth (meters); x = logarithm of heterotrophic bacteria (clumps/milliliter).

A further F-test of the data in Fig. 3 showed that the bacterial abundance at each depth was not significantly different for samples collected within the depth range 1–20 m, or within 50–400 m, in contrast to the highly significant difference in abundance determined between 1–20 m and 50–400 m. These observations indicate that microbial activity was especially high in the euphotic zone of the Strait of Georgia, even during the season of very low primary productivity.

PARTICULATE MATTER IN THE EUPHOTIC ZONE

The particulate matter in the sea water was measured quantitatively. Table 1 shows its size distribution at three stations and Table 2 shows the relative numbers of zooplankton and phytoplankton obtained at the same time. The predominant animals in the 350-μ net in December were *Pseudocalanus minutus* and *Acartia longiremis*; in the 200-μ net *Oithona spinirostris* and copepodite stages of *Pseudocalanus* were dominant; and in the 25-μ samples nauplii of *Pseudocalanus* and *Oithona* were dominant. Large numbers of *Coscinodiscus* were also gathered in the 25-μ net.

Most of the predominant zooplankton collected were herbivorous, although carnivorous ones such as *Sagitta* or *Pleurobrachia* were also detected occasionally in small numbers. Seston, retained on HA Millipore filter, was measured to be around 10 mg wet weight/liter of sea water at Station DB.

TABLE 1. Suspended matter (wet weight mg/20 m × m² in sea water).

Collection time:	Station 1[a]		Station 7[b]		Station DB[c]
	10:00	13:00	10:00	13:00	10:00
More than 350 μ	330	440	600	420	320
350–200 μ	570	590	850	600	220
200–25 μ	1,600	1,500	1,400	1,400	810
25–0.45 μ	190,000	...	250,000	...	450,000

[a]Observed on December 4, 1968.
[b]Observed on December 5, 1968.
[c]Observed on November 5, 1968.

TABLE 2. Qualitative and quantitative estimations of plankton (number/20 m × m² in sea water).

	Station 1[a]		Station 7[b]		Station DB[c]
Collection time:	10:00	13:00	12:00	14:00	10:00
350-μ net					
Animals	500	580	660	540	750
Plants	...	...	...	...	...
200-μ net					
Animals	1,400	6,800	3,800	5,400	5,000
Plants	150	120	480	160	...
25-μ net					
Animals	15,000	15,000	9,000	16,000	...
Plants	4,600	54,000	8,500	86,000	...

[a]Observed on December 4, 1968.
[b]Observed on December 5, 1968.
[c]Observed on November 5, 1968.

MICROORGANISMS ON SUBSTRATA IN THE EUPHOTIC ZONE

Bacteria on the different sizes of substrata (Table 1) are as shown in Fig. 4. Most of the microbial biomass was found on the particulate matter having a diameter of less than 25 μ at any sampling station. On every substratum the number of total bacteria as measured by direct microscopy was approximately from 10^2- to 10^5-fold greater than the number of heterotrophic bacteria as measured from plate counts on Medium 2216. As an exceptional case, large numbers of heterotrophic bacteria were measured on zooplankton at the station in Departure Bay.

The number of total bacteria per gram wet weight of plankton was calculated to be 10^9–10^{10} clumps, based on the data shown in Table 1 and Fig. 4. Assuming the digestive tract of zooplankton to be 5% of total body, calculated from the data in Marshall and Orr (1955), a maximum of about 10^{11} clumps

could be concentrated per 1 ml of the digestive tract of zooplankton. For a 2-mg (wet weight) zooplankter the quantity of bacteria required to fill the animal's digestive tract would be about 10^7 clumps, assuming again that 5% of the zooplankter's volume is digestive tract. This quantity of bacteria could be reasonably obtained by filtering between 10 and 100 ml of the sea water that contained (Fig. 4) 10^8 to 10^5 clumps/ml.

Taking into account the number of bacterial clumps/milliliter of sea water and the range in size of bacterial clumps (approximately 10-fold), then the corresponding concentration of bacterial carbon in the water column would be between 40 and 3000 mg C/m², assuming bacteria have a density of 1, a carbon to dry weight ratio of 0.5 and a dry weight to wet weight ratio of 0.1.

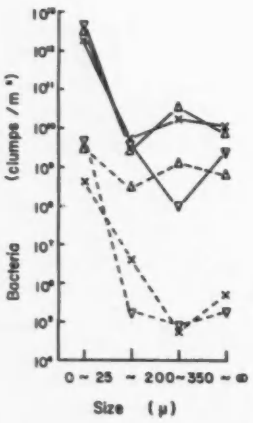

FIG. 4. Bacteria on the substrata of different sizes in the euphotic zone (m² × 20 m). ———— total bacteria; - - - - - - heterotrophic bacteria; △ station DB; × station 1; ▽ station 7.

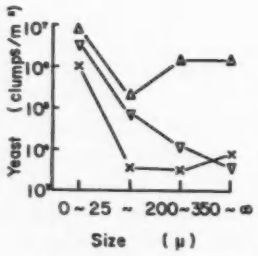

FIG. 5. Yeasts on the substrata of different sizes in the euphotic zone (m² × 20 m). △ station DB; × station 1; ▽ station 7.

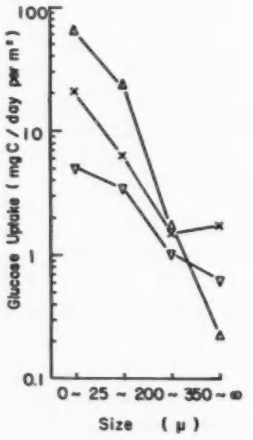

FIG. 6. Glucose uptake by microorganisms on the substrata of different sizes in the euphotic zone (m² × 20 m). △ station DB; × station 1; ▽ station 7.

Figure 5 shows the abundance of yeasts. By use of the Coulter counter (Sheldon and Parsons, 1967), the average cell volume of the yeasts in the sea was measured and found to be about 100 μ^3. Therefore, the biomass of yeasts was calculated to be about 4 μg C in a square meter of euphotic zone. The biomass of yeasts corresponded to less than 0.01% of the bacterial biomass in the sea and was primarily found to occur on the zooplankton. Some of them were yeasts pathogenic for planktonic crustaceans and were identified as belonging to the genus *Metschnikowia* (Seki and Fulton, 1969).

Figure 6 shows the glucose uptake of microorganisms on different substrata. As was already shown in Fig. 2, the rate of glucose uptake per unit volume

of water is higher in the euphotic zone. The organisms responsible for this uptake consisted of bacteria, fungi, protozoans, etc. Nearly the same distribution of microbial activity was observed as with the distribution of total bacteria (Fig. 4). However, relatively higher activity was observed on the substrata having diameters of 25–200 μ, and this may have been due to Protozoa and some kinds of phytoplankton (Provasoli, 1963).

Laboratory experiments showed that a *Pseudomonas* species (0.5 μ^3), collected from the surface water at station 1 by the microbiological method in 0.1% peptone (Difco) seawater medium, took up 5×10^{-11} μg C of glucose/cell per hour. Since a total uptake of about 20 mg C of glucose/square meter per day was usually measured at station 1, the microbial biomass can be calculated to be equivalent to a *Pseudomonas* biomass of ca. 400 mg C bacteria/m^2. This result is in the range of that obtained from the data on total bacteria. The original ratio of bacterial to zooplankton organic carbon in the water column was 10:1, i.e., 400 mg C bacteria/m^2 and 40 mg C zooplankton/m^2.

DISCUSSION

Since most of the heterotrophic microorganisms in the sea exist as aggregates, the measurement of their biomass has been almost impossible. As was discussed previously by Seki (1969), methods of measurements such as the physiological method (e.g., biomass indicated by respiration — Seki, 1969), or chemical methods (e.g., biomass indicated by ATP, DNA, RNA, etc. — Holm-Hansen et al., 1968) must be developed. By employing these methods, it is possible to obtain a measure of the microbial aggregates in sea water. However, all these methods still require to be thoroughly tested in the field and an estimation of the most probable microbial biomass by the use of several methods, such as has been employed in this study, may eventually be a desirable solution.

All the particulate matter having diameters larger than 350 μ were zooplankton, and most of the particles larger than 200 μ were also zooplankton, with a small number of phytoplankton. However, the fraction of phytoplankton increased with a decrease in particle size. This is ascertained by either the chlorophyll method or direct microscopy.

As most of the zooplankton were herbivorous, they were dependent on the phytoplankton for food, but bacterial clumps as well as aggregates composed of phytoplankton and heterotrophic microorganisms, may also have served as food for zooplankton. From a standing stock of bacteria that we determined to be between 40 and 3000 mg C/m^2 (or 2–150 μg C/liter) it is reasonable to suggest that the amount of bacterial carbon was at times adequate to support the maintenance and growth requirements of some filter-feeding zooplankton (Parsons and Seki, 1969).

The organic nutrients for the heterotrophic microorganisms were considered to be of terrestrial origin rather than from the primary productivity in the sea (Seki et al., 1969), which is very low during the winter months.

In conclusion, it appears that during the winter the bacterial biomass in the Strait of Georgia is at least equivalent to the biomass of phytoplankton

and that the bacterial aggregates may be a part of the food of filter-feeding organisms that reproduce during this period.

ACKNOWLEDGMENTS

The authors express their gratitude to Dr T. R. Parsons and C. D. McAllister for their important advice and discussion. They are also grateful to the captains and men of the research vessels CNAV *Endeavour* and CSS *Parizeau* for their cooperation during sampling.

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Alpha-Glycerophosphate Dehydrogenase As an Index of Iced-Storage Age of Fresh, Gutted Haddock (*Melanogrammus aeglefinus*)

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GOULD, EDITH. 1969. Alpha-glycerophosphate dehydrogenase as an index of iced-storage age of fresh, gutted haddock (*Melanogrammus aeglefinus*). J. Fish. Res. Bd. Canada 26: 3175–3181.

A new test is described for judging the iced-storage age of unspoiled gutted haddock, from early loss of quality to the first gross signs of spoilage. The test is a measure of the changing properties of alpha-glycerophosphate dehydrogenase in tissue fluid with time after death, and is interpreted as an indication of leaching of tissue during the first 7 days of storage. Such functional changes in an enzyme system are a particularly sensitive criterion of freshness in fish during the first 4 or 5 days of iced storage.

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INTRODUCTION

A CONTINUING PROBLEM IN FISHERIES RESEARCH is the lack of an objective test for true freshness in ice-stored fish. Such a test would be useful not only to processors who wish to select fish lots with a short iced-storage history, but also to fisheries scientists who wish to determine the relative success of experimental fish-handling methods.

The best available test suggested to date is based on levels of hypoxanthine, a product of nucleotide degradation. But, as with any test measuring the quantity of a metabolite, there are the problems of variable initial composition and variable catabolic rates, both inter- and intra-species.

A possibly more sensitive area for testing is the changing reactivities of enzyme systems in the ice-stored flesh. Most enzymes are particularly sensitive to their ionic environment, and as this changes, may undergo conformational changes that in turn affect their capacity to react either with specific ligands or under imposed stress (Gould, MS, 1969). The problem, then, was to find an easily extractable enzyme system that is measurably sensitive to changes in the concentration of metal cations in its assay medium.

A test to measure the reactivities of alpha-glycerophosphate dehydrogenase (L-glycerol-3-phosphate: NAD oxidoreductase, EC 1.1.1.8)[1] in centrifuged tissue fluid (CTF) from the flesh of ice-stored haddock (*Melanogrammus*

[1]Abbreviations used in this paper are: αGPdH = alpha-glycerophosphate dehydrogenase activity in the centrifuged fluid of whole tissue; CTF = centrifuged tissue fluid; NAD = nicotinamide adenine dinucleotide; Na-αGP = disodium alpha-glycerophosphate.

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aeglefinus) is reported below. The two properties studied are the reactivities of αGPdH in the CTF to added magnesium chloride and to heat.

MATERIALS AND METHODS

Preparation of Sample and Extract

Fresh, gutted haddock (less than 18 hr out of water) were stored on ice at 4 C. Each day, two fish were filleted and samples of tissue taken from each of the four fillets. All dark tissue was dissected from the dorsal anterior portion of each fillet, and a strip roughly 1 × 1 × 2 inches was cut from the remaining white tissue, making four samples of whole white tissue in all.

These whole pieces of tissue were centrifuged individually in a preparative ultracentrifuge at 4 C for 20 min at 20,000 *g*. The supernates, withdrawn with syringes, were the crude enzyme preparation, CTF, used for assay.

Heat Treatment of the Tissue Fluid

Aliquots (2 ml) of the CTF were heated in a water bath at 45 C for 20 min, cooled, and centrifuged for 10 min at 10,000 g and 4 C. The clear supernates were assayed for αGPdH activity in the same manner as was the untreated CTF.

Assay Procedure

The solutions listed below were pipetted directly into an optical cuvette having a light path of 1 cm. The rate of reduction of NAD was followed by recording the change in absorbance at 340 mμ over a period of 100 sec from the moment of addition of CTF. The reagent blank against which the change in absorbance was read contained everything but the CTF. The slope (of absorbance per unit time) from 30 to 90 sec was taken as the reaction rate or "αGPdH index" ($\Delta A^{340} \times 10^3$ per minute per 0.03 ml CTF). Of the Na-αGP, 95.99% was the alpha isomer and the remainder was the inactive beta isomer. The water used in preparing all solutions was doubly glass-distilled, solutions of substrate and coenzyme were prepared fresh daily, and the assays were read on a double-beam recording spectrophotometer.

The assay protocols were:

for cation-dilution experiment

NAD, 10 mg per ml	0.10 ml
Tris buffer, 0.1 M, *p*H 8.6	1.60 ml
Na-αGP, 0.1 M	0.03 ml
$MgCl_2 \cdot 6H_2O$, concentration varied: 0.00; 5 mM, 0.05 and 1.00 ml; 50 mM, 0.50 and 1.00 ml	
Distilled water to bring volume to 2.97 ml	
CTF to start reaction	0.03 ml

The control assays lacked only Mg^{++}.

The unit of activity, or "cation-dilution number," is calculated by (*a*) measuring the increase or decrease in the αGPdH index effected by the addition of increments of Mg^{++} to the assay mixture, as compared with the control (αGPdH index with no added Mg^{++}); (*b*) subtracting the increase effected by 5 μmoles from the increase or decrease effected by 50 μmoles; and (*c*) dividing this difference by 45.

for heat-treatment experiment

Assays were run on each CTF sample before and after heat treatment. The assay procedure was the same as for the cation-dilution experiment described above, except that the variable was concentration of substrate rather than magnesium chloride. The changes in the reaction mixture were:

Na-αGP, 0.1 M, concentration varied: 0.00, 0.05, 0.07, 0.09, 0.18, 0.39, and 0.50 ml	
$MgCl_2 \cdot H_2O$, 0.05 M	0.30 ml

The control assays lacked only substrate.

The unit of activity, or percent residual αGPdH activity after heat treatment, is calculated by dividing the αGPdH index of the supernate from heat-treated CTF by the index of the untreated CTF and multiplying by 100.

RESULTS AND DISCUSSION

αGPdH Sensitivity to Added Magnesium Chloride in Ice-Stored Haddock

Soluble αGPdH in ice-stored haddock proved to be markedly sensitive to increments of magnesium chloride added to the assay medium.

Earlier experiments established optimal ranges of concentration for substrate and for Mg^{++}, both of which are critical in demonstrating the changing reactivity of the enzyme. In this experiment, 3 μmoles of substrate was added, and the range of added Mg^{++} was from 0.25 to 50 μmoles. At concentrations of substrate higher than this, sensitivity of the enzyme to Mg^{++} was not so pronounced, and at lower concentrations the index was so low that sample variation became a problem.

In Fig. 1, the control assay (αGPdH index with no added Mg^{++}) is set at zero, and only the amounts of increase or decrease effected by Mg^{++} in relation to the control are plotted. This control value decreased slightly but steadily each day (Table 1); it is the difference in activity effected by the added Mg^{++}, however, that is important here. In amounts up to 25 μmoles, Mg^{++} stimulated the αGPdH activity in varying degree during the course of the experiment, with the greatest change occurring with 5 μmoles; but 50 μmoles, after effecting a small stimulus the first 2 days of storage, was progressively inhibitory. The changes in activity effected by 5 and 50 μmoles, therefore, were used to calculate the cation-dilution number, shown in Fig. 1 and tabulated in Table 1.

It is not surprising to see, in deteriorating animal tissue, certain functional changes in an enzyme system that requires optimal concentrations of several ligands. For normal functioning, αGPdH requires not only the presence of substrate, coenzyme, and divalent metal cation at critical concentrations, but also a critical spatial and sequential orientation of these upon the enzyme molecule itself. As leaching occurs (in the flesh of ice-stored fish) and the ionic character of the enzyme's environment changes, it is not unreasonable to expect that the enzyme's response to added ligands may also change. Figure 1 represents one example of such a response.

It is only remotely possible that the altering of αGPdH properties may be due to the gradual release into solution of mitochondrial αGPdH (L-glycerol-3-phosphate: (acceptor) oxidoreductase, EC 1.1.99.5). The mitochondrial enzyme requires an acceptor other than NAD and is tightly bound to the or-

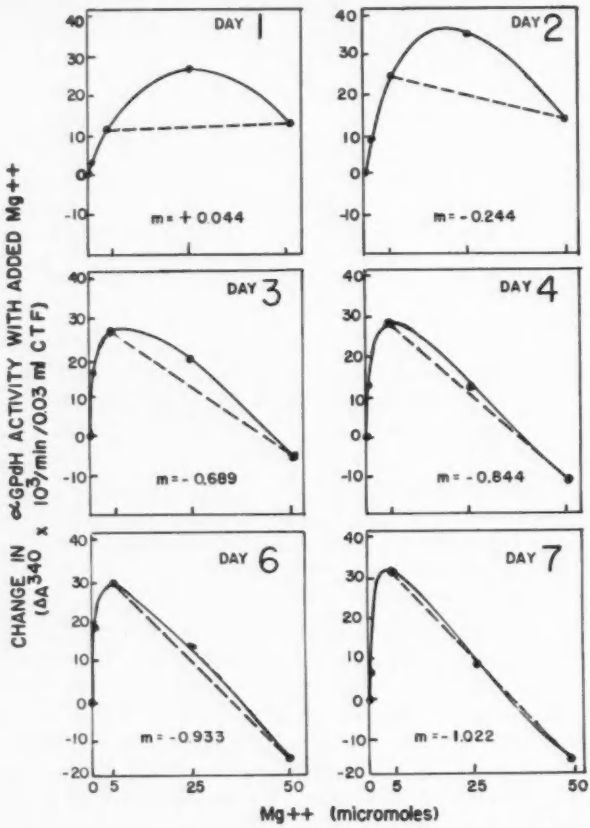

FIG. 1. Effect of added Mg^{++} upon αGPdH activity in the flesh of ice-stored gutted haddock. The broken lines, or slope (*m*), represent the cation-dilution number. Each point is the arithmetic mean for four individual samples. On the ordinate scale the control αGPdH index, with no added Mg^{++}, has been arbitrarily set at zero. The numbers above and below represent increase or decrease in the αGPdH index upon the addition of Mg^{++}.

ganelle membrane (Tipton and Dawson, 1968). Solubilization would require some special procedure, like digestion with phospholipase A (Ringer and Singer, 1959). The altered properties of αGPdH in this experiment, at least, may therefore be ascribed with some confidence to changes in the soluble enzyme.

The study was ended on the 8th day, when the first gross signs of spoilage became evident: the flesh of the remaining fish smelled musty and faintly acrid. Because the cation-dilution number for the 8th day showed neither the sharp change of the first 4 days nor the gentler approach to a plateau

TABLE 1. Comparison of changing properties[a] of αGPdH in ice-stored haddock.

Time of iced storage (*days*)	αGPdH activity without added Mg++ (*Index*)	Sensitivity to added Mg++ (*Cation dilution no.*)	Residual activity after heat (9 μmoles substrate) %[b]
1	87	+0.044	36
2	86	−0.244	42
3	85	−0.689	42
4	82	−0.844	47
6	80	−0.933	47
7	75	−1.022	52
8	66	−0.645	61

[a]Each figure represents the arithmetic mean of four individual samples.
[b]Residual αGPdH activity in the presence of 9 μmoles substrate was chosen for comparison in this table because the total increase in residual activity with time of storage was greatest at this concentration of substrate.

seen in the 6th and 7th days, it was felt wise to limit the test to very fresh fish. Indeed, the most striking changes occurred during the first 4 days, the period when taste panels usually find it most difficult to judge iced-storage age (Learson and Ronsivalli, 1969).

It should be noted that the fish used here were caught in the spring, and that no study has been made as yet of possible variations with time of year, age or sex of the fish, or site of fishing grounds.

EFFECT OF HEAT UPON αGPDH ACTIVITY IN THE CTF OF ICE-STORED HADDOCK

The tolerance to moderate heat of αGPdH activity varied both with concentration of substrate and with time of iced storage.

SUBSTRATE VARIABLE

The percent of the original αGPdH activity remaining in the tissue fluid after heat treatment (percent residual activity) is strongly dependent upon the concentration of substrate (Table 2). The heat-treated CTF retained only 30% of its original αGPdH activity when measured in the presence of 5 μmoles substrate, but demonstrated 90% residual activity in the presence of 50 μmoles, with intermediate values at intermediate concentrations of substrate.

These observations not only emphasize the importance of substrate concentration for optimal enzyme activity, but also demonstrate that a partial loss of tolerance to heat can be overcome by relatively large amounts of substrate.

TIME OF ICED STORAGE VARIABLE

As the time of iced storage increased, so also did the percent of residual αGPdH activity after heat (Table 2). From the 1st through the 8th day of

TABLE 2. Effect of heat upon αGPdH activity in ice-stored haddock, at differing concentrations of substrate.

Added substrate (*μmoles*): Time of iced storage (*days*)	5	7	9	18	39	50
	Amount of original αGPdH activity remaining after heat treatment (*residual activity*) (%)					
1	20	31	36	64	83	91
2	28	38	42	65	83	85
3	32	42	42	70	79	80
4	36	42	47	77	88	94
6	31	43	47	72	88	89
7	35	45	52	77	88	94
8	33	53	61	81	91	94
Total increase in residual activity (%)	13	22	25	17	8	–

storage, there was a definite increase in percent residual activity in the presence of 7 μmoles of substrate, a somewhat larger rise with 9 μmoles, and then lesser increases with 18 and 39 μmoles. There was no consistent change in percent residual activity with time of iced storage when either 5 or 50 μmoles was added. Because the largest increase in percent residual activity occurred with the addition of 9 μmoles of substrate, the data for this amount were used in Table 1.

These data indicate that αGPdH activity in the aging flesh of ice-stored haddock acquires, with time, an increasing tolerance to heat, especially within the range of 7–18 μmoles of added substrate. The reason for this phenomenon is not known. It is probable that there is more than a single catalytic site on the enzyme molecule, as three different ligands are required for optimal activity; but it does not necessarily follow that these catalytic sites share the same capacity to withstand heat. Another possibility, suggested by H. Groninger (personal communication), is that this increase in heat tolerance may be related in some fashion to the binding of some small molecules; Tanford (1968, p. 213) has cited work in which it was shown that a small amount of detergent stabilized native serum albumin against denaturation by urea.

Curiously, although the activity after heat increased with time of storage, the activity in the untreated CTF decreased slightly (Table 1). As a consequence, tabulating these data as percent residual activity not only lessened sample variation but also emphasized the phenomenon of increasing tolerance to heat.

CONCLUSIONS

A soluble alpha-glycerophosphate dehydrogenase has at least two properties that change measurably during early loss of freshness in ice-stored haddock: (1) a sensitivity to differing concentrations of added Mg^{++} and (2) a partial tolerance to moderate heat.

Measurement of these two changing properties of αGPdH is suggested as a possible test for early loss of quality in ice-stored haddock. It is less subject to the sample variation that inevitably accompanies measurement of changes in composition. It is also a sensitive indicator of changes occurring in fish flesh during the 1st week of iced storage, a period for which there is often wide variation in taste-panel data, particularly at the 1- to 4-day stage. It is not suggested for use with frozen and thawed fish because of the great loss of tissue fluid during the thawing process and because catabolic events move more rapidly in frozen and thawed tissue than in unfrozen tissue.

The test should be restricted, however, to commercially acceptable fish only. When the first signs of spoilage are grossly detectable, the test is no longer valid; it should be used for measuring only early loss of quality.

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Predation and the Evolution of a Stickleback (*Gasterosteus*)

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In western North America there are populations of *Gasterosteus* in which the male nuptial colour is a deep black rather than the normal bright red. Such black populations are usually allopatric to red populations, but in some areas the two forms occur in adjacent sympatry.

The difference in male nuptial colour and a number of other morphological and physiological traits reflect genetic differences between black and red populations. Male nuptial colour functions as a partial isolating mechanism. Mate selection experiments indicate that females from red populations rarely accept a black male when they have a choice between a red or black male. Females from allopatric black populations also show a preference for red males, but females from black populations immediately upstream from a hybrid zone appear to mate randomly. The significant difference in mate preference between allopatric and sympatric populations of black females is evidence for the reinforcement of male colour as an isolating mechanism. The selective mechanism reinforcing colour as an isolating mechanism is hybrid inferiority due to genetic incompatibility and aberrant behaviour in hybrid males.

A hypothesis is presented that persistent differential predation by an endemic predator (*Novumbra*) on the young concentrated near the male nest site was the selective force responsible for the evolution of the black genotype. Experiments demonstrate that *Novumbra* is differentially attracted to red males when given a choice between red and black males, and that the young of black sticklebacks possess an innate behavioural response to *Novumbra* that makes them significantly less vulnerable to predation by *Novumbra*.

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INTRODUCTION

The effects of predation on the process of speciation are poorly understood. Much of the work on genetic polymorphism, especially that on mimicry, indicates that differential predation is an important selective force. Whether this selective force accelerates or retards the process of speciation is a matter of controversy. Discussing the endemic fish faunas of various African lakes Worthington (1940) suggests that the interlacustrine differences in the numbers of endemic species are due to differences in predation pressure, and that predation has a restrictive effect on speciation. Fryer (1959, 1960) reverses the argument and contends that predation has accelerated speciation in some of the African lakes. Mayr (1963) briefly reviews the controversy, and suggests that "the truth is, presumably, somewhere between the extremes of Worthington and Fryer." However, Mayr also indicates that some retardation of speciation by predation is highly probable.

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The present paper attempts to document a case in which the evidence, as I interpret it, indicates that predation played a dominant role in genetic divergence and acquisition of a partial isolating mechanism.

The threespine stickleback, *Gasterosteus aculeatus*, is abundant in the boreal coastal regions of North America, Europe, and Asia. The range of the species is disjunct, and the Atlantic and Pacific coastal populations are separated by wide areas along the arctic coasts of North America and Siberia where the species is absent. The morphological variation in *G. aculeatus* is notorious, and Hubbs (1929) commented that "the systematic interpretation of the sticklebacks has long been — and still remains — one of the most perplexing problems in ichthyology."

Although the species is morphologically variable, there are some characteristics that appear to be relatively constant over most of its wide geographic range. One such character is male nuptial colour. Male *G. aculeatus* are drably coloured most of the year, but during breeding season they develop brilliant red throats and blue irises. In breeding condition the males are aggressive, establish territories, build nests, guard the eggs, and show parental care of the young. Pelkwijk and Tinbergen (1937) indicate that the red male nuptial colour functions in aggression between males and in the male courtship of females. They demonstrated that a model painted red on the underside was attacked more readily by breeding males than a model without the red colour, and that gravid females will respond positively (give the "head-up" response) to models with the underside painted red but not to models that lack the red colour. These experiments indicate that the red male nuptial colouration plays an important role in sexual selection within the species. Therefore, it is not surprising that the male nuptial colouration appears to be relatively constant over the wide and disjunct geographic range of the species.

However, in British Columbia and Washington there are some populations in which the male nuptial colours differ radically from normal *G. aculeatus*. Such a population occurs in the Chehalis River, an isolated coastal drainage in the western half of Washington State (Fig. 1). Within the Chehalis system many of the local *Gasterosteus* populations contain males that develop jet black nuptial colours. In these populations the males are a dull mottled colour most of the year and develop black colour only when breeding. Such populations are scattered throughout the Chehalis system and adjacent rivers. Usually these "black"[1] populations are allopatric to normal "red" populations, but in some streams both forms occur and their distributions are contiguous.

The presence of black *Gasterosteus* populations in the Chehalis system raises a number of questions. Are the black populations genetically distinct from normal red populations? If so, do the differences in male nuptial colour function as an isolating mechanism? And finally, what is the adaptive signifi-

[1]For convenience the terms "black" and "red" will be used throughout this paper. *Black* refers to populations in which the males are black during the breeding season; and *red* refers to normal *G. aculeatus*. The females of both forms are cryptically coloured throughout the year.

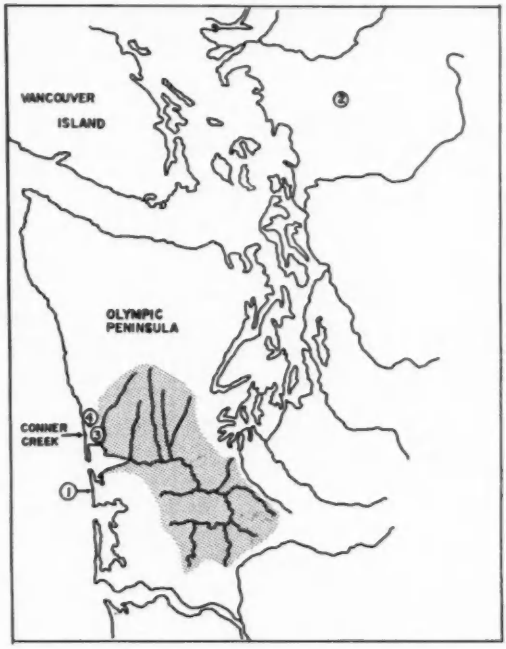

FIG. 1. Stippled area encloses the Chehalis River system, western Washington. The numbered areas are localities listed in the text.

cance of being black? The last question is the fundamental one in that the other questions, if answered affirmatively, imply that the black breeding colour has adaptive significance. Granting a selective advantage in being black, it must be associated with some factor unique to the Chehalis system, since in almost all other recorded *Gasterosteus* populations the majority of the males are red. The only recorded exception that I know of is *G. wheatlandi* of the Atlantic coast (the breeding males are yellow). In addition, Mayer Lake on the Queen Charlotte Islands, British Columbia, contains a population in which male nuptial colour varies from black to red (E. E. Moodie, personal communication).

Since three interrelated questions are involved in this study, the data are presented as three series of experiments connected by a series of field observations. Each series of experiments was designed to answer one of the questions, and the field observations supply the relevant ecological background.

MATERIALS

All of the sticklebacks used in the experiments were obtained in western Washington and represent only the partially plated, unkeeled (*leiurus*) form. The primary study area was the Chehalis River including tributaries (Fig. 1). Most of the red sticklebacks came from two areas: Heather Ditch (1 on map) near Grays Harbor, and a ditch beside Clearbrook Road near Sumas (2 on map), Washington (about 200 miles north of the other population). The black sticklebacks

were obtained from a pond (3 on map) near the Humptulips River and an unnamed stream (4 on map) near Carlisle. Both localities are in Grays Harbor County, Washington.

Field observations were conducted throughout the Chehalis system and nearby watersheds, but were concentrated on a small stream, Conner Creek, which enters the Pacific Ocean at Ocean Beach, Washington (Fig. 2).

The laboratory work was started at the College of Fisheries, University of Washington, and finished at the Institute of Fisheries, University of British Columbia.

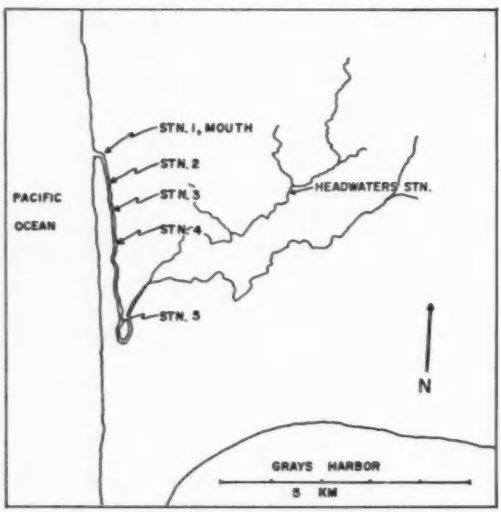

FIG. 2. Conner Creek, Gray's Harbor County, Washington. The arrows indicate collecting sites mentioned in text.

EXPERIMENTS AND FIELD OBSERVATIONS

GENETIC DIFFERENCES

The first series of experiments was designed to test whether the observed differences between red and black sticklebacks are inherited. The observed differences are morphological and physiological. Aside from the colour difference in breeding males two other morphological differences in phenotype were noted: the number of gill rakers and the placement of the dorsal spines. To test whether these differences are heritable, the eggs of allopatric populations of black and red sticklebacks were fertilized in the laboratory and raised in divided aquaria. The partitions in the aquaria were of fine screen through which water circulated, and both forms were exposed to essentially the same environment. The water temperature was 18 C; the laboratory light regime was variable but the same for all tanks. The fish were raised to sexual maturity, used in other experiments, and then preserved and used for morphometric analysis.

Gills rakers were counted on the left gill arch, and the interspine ratio was obtained by dividing the distance between the first and second dorsal spine into the distance between the second and third dorsal spine. The results

of the experiment clearly indicate that male breeding colour and the other morphological differences between black and red sticklebacks are heritable (Table 1).

TABLE 1. Morphological differences between wild and laboratory-reared black and red sticklebacks and F_1 hybrids.

		Gill rakers				Interspine ratio			
	Male nuptial colour	Range	$\bar{X}$	SD	No.	Range	$\bar{X}$	SD	No.
Black (Humptulips Pond)									
Wild	Black	12–18	15.8	1.1	80	0.8–1.5	1.1	.15	80
Lab reared	Black	12–18	16.0	1.0	30	0.7–1.5	1.1	.16	30
Red (Heather Ditch)									
Wild	Red	16–23	20.8	1.2	80	1.2–1.9	1.5	.20	80
Lab reared	Red	16–23	20.5	1.1	30	1.2–1.8	1.5	.22	30
F_1 hybrids (lab reared)	Intermediate but variable	15–21	19.1	1.6	30	1.1–1.6	1.3	.25	30

Field observations in the Chehalis River system indicated that black sticklebacks are usually found at least 1 km inland from the sea, whereas red populations are abundant in the sloughs and ponds behind sand dunes less than 1 km from the sea. This suggested that there might be a difference in salinity tolerance between the two forms. The salinity tolerances of adults and eggs were tested. The adults tested included wild allopatric populations of red and black sticklebacks, and laboratory-reared adults originating from the same populations. The wild adults were taken in April and held at 18 C for 4 days and then tested in 38-liter aquaria at 18 C and 28.5‰ sea water. The laboratory-reared adults were tested at the same time and under the same conditions. The size range was 35–50 mm standard length. Controls were run in similar containers but in fresh water, and showed no mortality through 7 days.

The mean time to the end point (cessation of normal swimming and floating to the surface) differs markedly between the wild, allopatric populations of the two colour forms (Table 2). Similar differences were observed between laboratory-reared populations of the two forms. However, there were no major differences between the laboratory-reared populations and the wild populations from which they were taken. This suggests that the observed differences in salinity tolerance between black and red sticklebacks are inherited.

The salinity tolerance of fertilized eggs was also tested. The eggs were obtained from the same wild allopatric populations and laboratory-reared adults. In all instances the eggs were artificially fertilized in fresh water at 18 C. The experimental eggs were transferred after 10 min to aerated incubating jars containing 700 ml of 28.5‰ sea water. The eggs were incubated at 18 C.

TABLE 2. Adult salinity tolerance of wild and laboratory-reared red and black populations (values are time to end point in minutes; temperature 18 C; salinity 28.5‰).

	Black (Humptulips Pond)				Red (Heather Ditch)			
	Range	$\bar{X}$	SD	No.	Range	$\bar{X}$	SD	No.
Wild	50–280	180	55	30	1460–? 10 alive after 7 days	4320	1296	30
Lab reared	53–270	180	56	30	1440–? 8 alive after 7 days	4330	1330	30

Each egg batch was divided in half, with one half used as the experimental (in sea water) and the other half incubated in fresh water as a control.

Survival of eggs (Table 3) from wild red sticklebacks in sea water is high (90–100%), whereas the survival of eggs from wild black sticklebacks in sea water is zero (the zygotes died at gastrulation). Again, the results obtained from the zygotes of laboratory-reared adults suggest that this difference is inherited.

TABLE 3. Salinity tolerance of zygotes from wild and laboratory-reared red and black populations (temperature 18 C; salinity 28.5‰).

	Experimentals (28.5‰ salinity)		Controls (fresh water)	
	% eggs hatching	No.	% eggs hatching	No.
Black (Humptulips Pond)				
Wild	0	216	90–100	278
Lab reared	0	200	90–100	197
Red (Heather Ditch)				
Wild	90–100	228	90–100	243
Lab reared	90–100	185	90–100	212

Conclusions — There are heritable differences in male breeding colour, gill raker number, interspine ratio, adult salinity tolerance, and egg salinity tolerance between allopatric populations of red and black sticklebacks.

HYBRIDIZATION AND MATE PREFERENCE

The first series of experiments indicated that there are genetic differences between allopatric populations of black and red sticklebacks. Field studies during the same period revealed some areas in the Chehalis River system where black and red sticklebacks occur in adjacent sympatry. Field observations also indicated that the breeding seasons overlap extensively (March to July

for red sticklebacks and late February to early September for black sticklebacks) and that breeding occurs in the same, or contiguous areas. These observations raised the question of hybridization between the two forms, and possible isolating mechanisms. A series of experiments was designed to determine: (1) whether hybrids could be formed (and if so, what were their phenotypic characteristics, especially male breeding colour); (2) whether hybrids were sterile or if there was any loss of viability in hybridization; and (3) if there was any mate selection associated with the different male breeding colours.

Hybridization — Hybrids were produced by artificially crossing allopatric populations of red and black sticklebacks. Each egg batch obtained from a female was divided: one half was fertilized with a male from her own population (the control), the other half fertilized with a male of the opposite colour. The eggs were incubated in aerated 700-ml jars at 18 C. The results indicate a slight (5%) but consistent loss of viability in the reciprocal crosses compared with the controls (χ^2 on totals = 17.1, $P < 0.001$, Table 4).

The offspring of these crosses were raised to sexual maturity to determine the breeding colours of hybrid males and to determine whether the F_1 hybrids are sterile. At sexual maturity hybrid males develop breeding colours that are intermediate between black and red sticklebacks (Table 1). There is considerable variability in hybrid male colour, and they range from black with some red on the mouth and throat to red with irregular areas of black.

Hybrid males and females were then backcrossed to both parental forms and crossed among themselves. When hybrid males were backcrossed to either black or red females the egg batch was split and one half used as a control (fertilized by a nonhybrid male of the female genotype). All crosses were replicated three times.

The fertilized eggs were examined 24 hr after fertilization and all eggs that had failed to begin division were removed. The difference in the number of infertile eggs between experimental batches and controls was used as a crude estimate of sterility. The estimate of viability is based only on fertile eggs.

The results of these crosses indicate a slight (5%) reduction in fertility in the F_1 hybrids (χ^2 on totals = 14.9, $P < 0.001$, Table 5), and about a 50% average reduction in viability of backcross zygotes (χ^2 on totals = 144, $P < 0.001$, Table 6). However, the results are variable, and some backcrosses show high survival.

Five F_1 hybrid males were reared to sexual maturity and allowed to breed with either black or red females in an attempt to determine if they could successfully rear offspring. Hybrid males perform all of the normal *Gasterosteus* parental behaviour (van Iersel, 1953) but their fanning behaviour is much reduced (Fig. 3). This results in an abnormally high egg mortality in nests of hybrid males (Table 7).

Mate selection — These experiments were designed to test if there is any mate preference associated with male colour pattern. Preliminary experiments

TABLE 4. Survival to hatching of fertilized eggs in crosses between allopatric populations of black (Humptulips Pond) and red (Heather Ditch) sticklebacks. Temperature 18 C.

	Black ♂ × red ♀ fertile eggs	No. hatched	Red ♂ × black ♀ fertile eggs	No. hatched	Black control fertile eggs	No. hatched	Red control fertile eggs	No. hatched
	109	96	131	105	92	89	104	99
	118	112	89	84	78	73	112	108
	114	102	103	93	107	103	97	94
Total	341	310	323	282	277	265	313	301
% survival		91		90.5		96		96

χ^2 (on totals) = 17.1 $P < 0.001$

TABLE 5. Fertilization success of F_1 hybrid males.

	F_1 hybrid ♂ × black ♀		F_1 hybrid ♂ × red ♀		Black control		Red control	
	No. eggs	No. fertile	No. eggs	No. fertile	No. eggs	No. fertile	No. eggs	No. fertile
	134	121	103	96	112	112	110	108
	92	90	122	118	88	87	86	86
	112	104	107	103	61	61	132	131
Total	338	315	332	317	261	260	328	325
% fertilization		93		96		99		99

χ^2 (on totals) = 14.9 $P < 0.001$

TABLE 6. Survival to hatching of backcrosses, controls, and F_2.

	F_1 hybrid ♂ × black ♀		F_1 hybrid ♂ × red ♀		Black ♂ × F_1 hybrid ♀		Red ♂ × F_1 hybrid ♀	
	No. fertile eggs	No. hatched	No. fertile eggs	No. hatched	No. fertile eggs	No. hatched	No. fertile eggs	No. hatched
	45	40	61	44	44	12	30	10
	56	18	103	54	73	22	50	15
	134	60	107	38	70	56	80	60
Total	235	118	271	136	187	90	160	85
% survival		50		50		48		53

	F_1 hybrid ♂ × F_1 hybrid ♀		Black control		Red control	
	No. fertile eggs	No. hatched	No. fertile eggs	No. hatched	No. fertile eggs	No. hatched
	62	9	86	84	105	101
	80	12	73	71	94	90
	60	40	98	93	112	107
Total	202	61	257	248	311	298
% survival		30		97		96

χ^2 (on totals between backcrosses and controls) = 144 $P < 0.001$

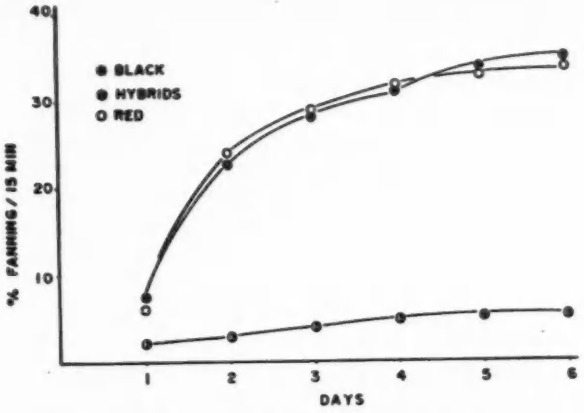

FIG. 3. Percent of time spent fanning the nest by black, red, and F_1 hybrid males. The points are means (N = 5 in each instance). Eggs removed at 6 days. Temperature 18 C.

TABLE 7. Mortality in nests cared for by black, red, and F_1 hybrid males. The eggs were removed from the nest on the 7th day. All females were from 42 to 44 mm in standard length (expected egg number is from 100 to 140).

Black males		Red males		F_1 hybrid males	
Live eggs	Dead eggs	Live eggs	Dead eggs	Live eggs	Dead eggs
110	2	108	0	0	All decayed
100	8	131	0	0	All decayed
90	6	80	3	42	13 countable
85	0	107	8	40	6 countable

indicated that given no choice, females from black populations will mate with red males, and that females from red populations will mate with black males. In addition, there seems to be no obvious behavioural differences between black and red sticklebacks. Both forms show the typical *Gasterosteus* courtship behaviour described by Tinbergen (1951). In the laboratory there are no obvious differences in nest site or nest construction.

Female mate preference was tested in 95-liter glass aquaria. The bottoms of the aquaria were covered with coarse gravel. Two similar areas, about 5 × 10 cm at opposite ends of the aquaria, were covered with mud, and it was here that the males constructed their nests. A plexiglass partition 10 cm wide was suspended in the center of each aquarium dividing it into three chambers: a large chamber at each end, and the 10 cm wide partition in the center. A black male was placed in one large chamber and a red male in the other. Usually two aquaria were in use at any one time and the position of the two types of males was always reversed to avoid any bias due to the lighting

in the room. At first, observations were made using a mirror and an over-head light in an otherwise darkened room. Later, observations were made through a one-way mirror.

Gravid females were first tested with a male of their own genotype in a separate tank. If the female was receptive, that is, if she gave the head-up signal (Tinbergen, 1951) when courted, she was removed and placed in the testing tank. In the test tank a black male with a nest was in one large chamber and a red male with a nest in the other large chamber. The gravid female was then placed in the center chamber. A record was kept of which male (black orred) first courted her, and to which male she first responded (gave the head-up signal).

The females tested were from a red allopatric population (Clearbrook), a black allopatric population (Humptulips Pond), and a black population immediately upstream from a hybrid zone (this population and the hybrid zone will be discussed in detail later). Females from a specific population were tested in series and the results plotted on a sequential analysis chart (Cole, 1962). The series was continued until either a preference, or no preference, was indicated. The results were later compared using a chi-square test at a 0.05 level of significance (Table 8).

TABLE 8. Female mate preference tests: the number of time females from the indicated populations responded to black and red males in a choice situation (each female was tested once).

Allopatric black ♀♀			Allopatric red ♀♀			Black ♀♀ adjacent to a hybrid zone (Conner Creek, station 4)		
Black ♂	Red ♂	No.	Black ♂	Red ♂	No.	Black ♂	Red ♂	No.
15	32	47	11	53	64	39	29	68
$\chi^2 = 7.2$ $P < 0.01$			$\chi^2 = 27$ $P < 0.005$			$\chi^2 = 1.4$ $P > 0.250$		
χ^2 between allopatric black and red populations = 3.29 $P < 0.05$								
χ^2 between allopatric black and sympatric black populations = 9.6 $P < 0.01$								

Females from allopatric red popuiations show a strong preference for red males ($P < 0.005$), and females from allopatric black populations also shown a significant ($P < 0.01$) preference for red males. Females from the black population immediately contiguous to the hybrid zone (see section on Field Observations for details) show no statistical preference ($P < 0.25$) for either red or black males and appear to mate randomly. However, females from this population differ significantly ($P < 0.01$) in their response to black and red males when compared with either allopatric black or allopatric red females.

Conclusions — There is a slight (5%) loss of viability in the F_1 cross between black and red sticklebacks. Hybrid males are intermediate in their

colour pattern and morphology. F_1 hybrids have a slightly reduced fertility and about a 50% average reduction in viability when F_1 hybrids are back-crossed to the parental forms (however, the results are variable). This suggests hybrid breakdown (Grant, 1963). Also, F_1 hybrid males do not fan their nests normally and this results in a high mortality in egg clutches cared for by hybrid males. Females from allopatric black populations also show a preference for red males. Females from a black population contiguous to the hybrid zone show no mate preference.

Field Observations

Field observations were made throughout the study. At first they were exploratory and covered the entire Chehalis River system. Later they were concentrated in one area where black and red sticklebacks occurred sympatrically. This area was Conner Creek, a small sluggish, tea-coloured stream (about 12 km long) that enters the Pacific Ocean at the town of Ocean Beach in Grays Harbour County, Washington.

Collecting stations were fixed at 0.5-km intervals from the mouth to 2.5 km upstream (Fig. 2). Occasional samples were taken above this point. Figure 4 shows the distribution of red males, black males, and "hybrid" males (males with intermediate breeding colours similar to laboratory-reared hybrids) during the breeding season in Conner Creek. Black males are rare at the mouth of the stream, but increase in frequency upstream to station 4. From station 4

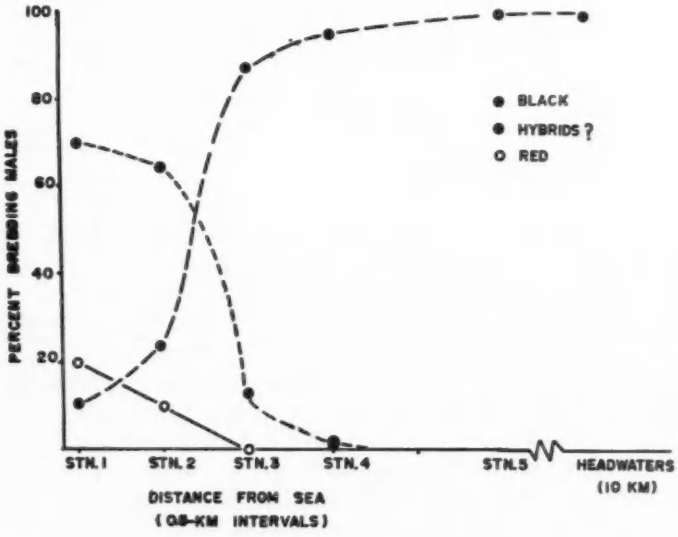

Fig. 4. Percent occurrence of black, red, and intermediate (hybrid?) males at six sites on Conner Creek.

to the extreme headwaters only "pure" black males occur. "Pure" red males are most abundant at the mouth of the stream and do not occur above station 2 (0.5 km from the mouth). "Hybrid" males are abundant from the mouth up to station 2, and then decrease rapidly in abundance. Only one "hybrid" male was taken at station 4 in 3 years of collecting. The distribution of breeding males in Conner Creek strongly suggests that above station 4 only black sticklebacks occur, whereas below station 4 there is a "hybrid zone," and a small population of red sticklebacks at the mouth of the stream. The actual mouth of Conner Creek is very unstable and can shift over 0.5 km in position during a storm. The point I designate as the mouth is the last stable portion of the stream (Fig. 2).

Figure 5 shows the distribution of gill-raker numbers at stations in Conner Creek as compared with an allopatric red population (Heather Ditch) and an allopatric black population (Humptulips Pond). The mean gill-raker count at station 1 (the mouth of Conner Creek) is high (21.2), the sample is bimodal (modes at 18 and 21), and the standard deviation is large (relative to the samples taken from station 3 and above). The mean at 21.2 suggests the presence of red sticklebacks and the high (3.4) standard deviation suggests the presence of hybrids and backcrosses. At station 2 the sample is still bimodal (modes at 17 and 21), the mean is 17.5, and the standard deviation 3.9. Again, this suggests an area of hybridization. From station 3 to the extreme headwaters

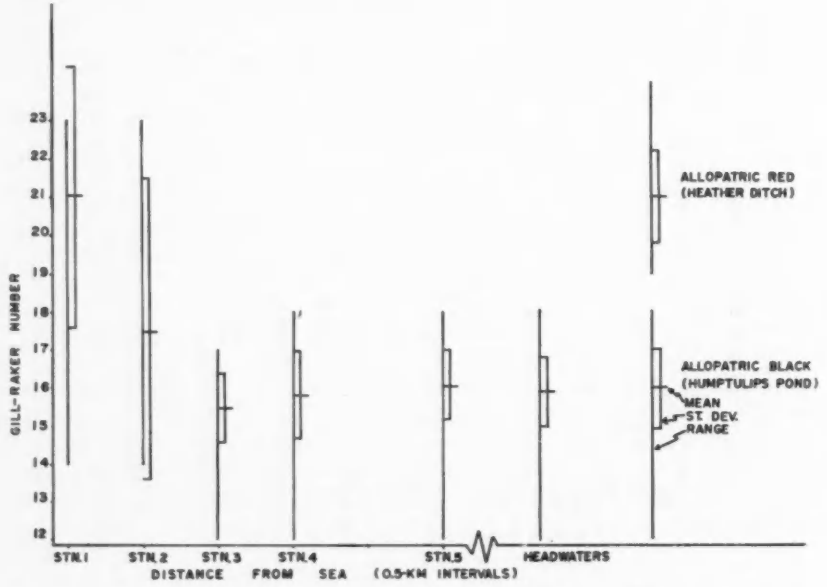

FIG. 5. The distribution of gill rakers at various stations in Conner Creek compared with an allopatric red and an allopatric black population.

of Conner Creek the distributions of gill rakers are unimodal with means between 15 and 16 and the variance is small. They correspond well to the allopatric black population, and suggest that above station 3 no hybridization is occurring.

Figure 6 shows the survival of fertilized eggs in sea water (28.5‰). The eggs were artificially fertilized in the laboratory, and were obtained from females taken at the indicated stations and fertilized with whatever type of male was predominant at that station. Black, red, and hybrid females are very difficult to distinguish (they show no breeding colours), and so the possibility cannot be excluded that the females used in this experiment were not always of the same genotype as the males. However, the survival of fertilized eggs in sea water (Fig. 6) gives essentially the same picture as the distribution of

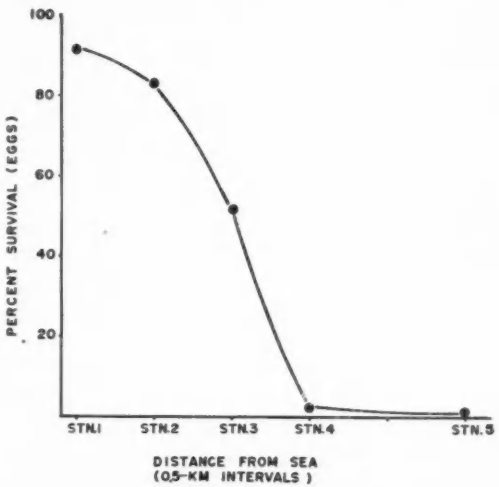

FIG. 6. Survival in 28.5‰ sea water of fertilized eggs taken at different stations along Conner Creek. Temperature 18 C.

breeding males and the distribution of gill-raker numbers. Survival is high at station 1 (and similar to the results for allopatric red populations listed in Table 3), and drops off rapidly upstream. From station 4 up to the headwaters of Conner Creek the survival is zero (as would be expected if the population is "pure" black above station 4).

The striking similarity between the results obtained from two morphological characters (male breeding colour and the number of gill rakers) and a physiological character (survival of fertilized eggs reared in sea water) suggests that they are reflections of the same phenomenon: the distribution of red, black, and hybrid genotypes in Conner Creek. It appears that in Conner Creek only the black genotype is found above station 4 (2.5 km from the mouth), below station 3 hybrids are abundant, and it is only in the first 0.5 km of the stream that the red genotype is present. The change from the hybrid

zone to the area occupied exclusively by black sticklebacks is quite abrupt (Fig. 4).

The only obvious physical factor in the environment that shows a similar pattern is salinity (Fig. 7). The lower portions of Conner Creek are myxohaline, but the salinity drops off rapidly upstream. This suggested that salinity might be affecting the distribution of sticklebacks in Conner Creek. To test this, a transfer experiment was conducted. Four live-boxes were placed in the stream: two each at stations 1 and 4. In the live-boxes at station 1, 20 sticklebacks from station 1 (controls) were placed in one box and 20 sticklebacks from station 4 in the other box. At station 4, 20 sticklebacks from station 4 (controls) were placed in one box and 20 sticklebacks from station 1 in the other. After 1 week, all of the station 4 sticklebacks transferred to station 1 were dead. There was no mortality in the box containing the controls. At

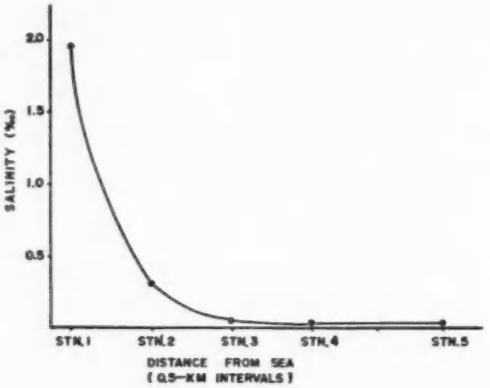

FIG. 7. Salinity (‰) at different stations along Conner Creek, July 1, 1966, low tide.

station 4 there was no mortality in either the control or experimental boxes, and after 3 weeks the experiment was terminated. The experiment was replicated three times, always with similar results, although in the later experiments, the mortality in the station 4 fish transferred to station 1 was not total.

This experiment suggests that the salinities encountered at the mouth of Connor Creek are sometimes sufficient to limit the downstream distribution of black sticklebacks. However, the experiments also suggest that the salinity characteristics of Conner Creek are not a barrier to the upstream penetration of red sticklebacks.

SELECTIVE ADVANTAGE OF BLACK MALES

The earlier series of experiments indicates that there are no strong genetic incompatability barriers to hybridization between black and red sticklebacks in the first generation, although there is a 50% reduction in viability in hybrid backcrosses. This suggests that some gene exchange between the black and

red genotypes is possible. In addition, the field observations indicate a "hybrid zone" in Conner Creek. The experimental evidence also suggests that there is no physical barrier to the upstream penetration of the red genotype. Yet in Conner Creek the "hybrid zone" ends abruptly below station 4 and above this point there is no evidence of gene-flow from the red population into the black population. This implies that above station 4 the black genotype has some strong selective advantage over the red genotype. Since, in competitive experimental situations, red males have a sexual advantage, it is reasonable to argue that the black colour in black males must have a high selective value in certain situations, and that this more than offsets their sexual disadvantage.

A number of factors suggested that the selective advantage of black sticklebacks in most of Conner Creek might be associated with predation. First, the black colour is less obvious (at least to the human eye) than the red, particularly in the highly stained waters of Conner Creek. Secondly, the control of the breeding colour in black sticklebacks is peculiar. Red male sticklebacks develop their breeding colours slowly with the onset of breeding season. Once the red colour is developed it is usually retained throughout the breeding season. The red colour may vary in intensity but is only rarely lost. In black males the black pigment also develops slowly and is retained throughout the breeding season. However, unlike red males, black males can control and change their colour. A male showing intense black colour, can fade to a drab-mottled colour (very similar to the normal black female colour) in a minute. A disturbance of a breeding black male (such as rapping on the aquarium) will sometimes elicit this response. It is unlikely that such a response would have evolved unless it was of some advantage. The most obvious result of this response is that the male's colour becomes increasingly dull and perhaps less conspicuous than when he is black.

The fact that throughout most of its circumboreal range the male three-spine stickleback is typically red during the breeding season, and as far as is known, exclusively black populations are unique to the Chehalis River system, argues that if the black stickleback evolved its colour as a response to predation, the predator is probably also unique to the Chehalis River system. Such a potential predator does exist. The western mudminnow, *Novumbra hubbsi*, is a small carnivorous fish endemic to the Chehalis River and a few other streams in western Washington.

The suspicion that *Novumbra* is involved in the relationship between red and black sticklebacks is strengthened by its distribution within the Chehalis system, and in Conner Creek in particular. Within the Chehalis system there is a striking association between the presence of *Novumbra* and the presence of black sticklebacks (Fig. 8). This association is particularly noticeable along the shores of Gray's Harbour (the estuary of the Chehalis River). On the north shore of Gray's Harbour *Novumbra* is abundant in areas above tidal influence in many of the small streams (Campbell Slough, Chenois Creek, and Grass Creek) entering the harbour. Male sticklebacks in areas of these streams where *Novumbra* is abundant are black. Along the south shore of Gray's Harbour

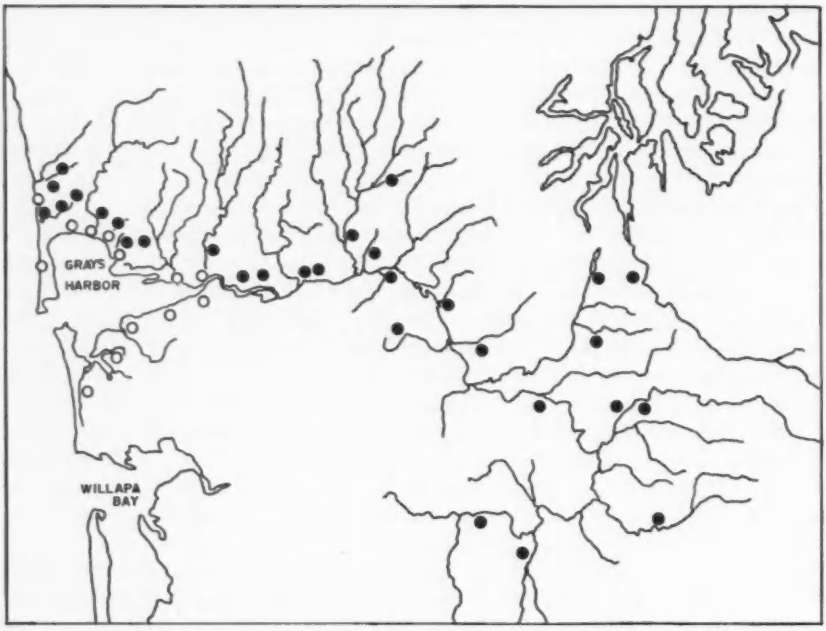

FIG. 8. Distribution of red (○) and black (●) sticklebacks in the Chehalis system. *Novumbra* occurs at all of the black localities.

Novumbra is absent and all of the streams examined (five unnamed streams and the Johns River) contained red sticklebacks, even in areas above tidal influence.

Within Conner Creek this association between black males and *Novumbra* is also apparent. The distribution of *Novumbra* in Conner Creek is essentially the same as the distribution of black sticklebacks (Fig. 4), and where *Novumbra* is rarest (at the mouth) the frequency of red males is highest.

The following series of experiments was designed to test if *Novumbra* preys differentially on black and red sticklebacks, and if so, whether the breeding colour of male sticklebacks is associated with the differential predation. *Novumbra* is too small (adults seldom exceed 90 mm) to prey on adult sticklebacks. If predation by *Novumbra* is a significant factor, it must be predation either on the eggs in the nest or on the young after they emerge from the nest.

Predation experiment — Laboratory-reared larvae of red and black sticklebacks were used throughout this experiment. Twenty larvae of either red or black sticklebacks were placed in a 38-liter aquarium and allowed to adjust to the tank for 30 min. An adult *Novumbra* was then added. Observations were made through a one-way mirror for a 20-min period starting after the first strike was observed. Each *Novumbra* was used only once and then discarded.

Novumbra locates its prey visually and is particularly sensitive to movement. Typically, *Novumbra* will respond to movement by fixing its eyes on the moving object and hanging motionless (except for a gentle sculling of the pectoral fins) in the water. *Novumbra* then glides towards its prey by sculling with the pectoral fins until it is about one-half to a full body length away from the prey. It then stops and stares intently before making a final sudden lunge forward.

During each experiment the following data were recorded: the number of times *Novumbra* visually fixed on the larva, the number of times it attempted to position itself for a strike, and the number of times it actually struck. After the 20-min observation period the *Novumbra* was removed and the surviving larvae counted.

The number of times *Novumbra* attempted to position itself for a strike was used as a measure of preference for either larvae from red or black populations (the larvae are similar in shape, size, and colour). There was no preference ($P > 0.75$) by this measure (Table 9). However, there was a significant

TABLE 9. The number of times *Novumbra* attempted to position itself for a strike and the number of times it actually struck. The prey are 12-day-old black (Humptulips Pond) and red (Clearbrook) stickleback larvae. Three separate trials are listed.

	Attempts at position		Strikes	
	Black larvae	Red larvae	Black larvae	Red larvae
	55	52	16	34
	50	55	12	21
	51	50	14	28
Total	156	157	42	83
	$\chi^2 = 0.006$	$P > 0.75$	$\chi^2 = 13.6$	$P < 0.001$

difference ($P < 0.01$) in the number of actual strikes *Novumbra* made. More strikes were made at red larvae than black larvae. This difference apparently resulted from a difference in the behaviour of the larvae rather than a preference for red larvae on the part of *Novumbra*. *Novumbra* attempted to position itself for a strike equally often with black larvae, but black larvae took evasive action before *Novumbra* was close enough to strike. This evasive action consisted of a series of very rapid darts away from *Novumbra*, usually to the surface where the larvae then remained motionless. The black larvae remained motionless even if the *Novumbra* followed, and *Novumbra* rarely struck at these motionless larvae. The larvae of red sticklebacks usually did not take evasive action as the *Novumbra* positioned itself for a strike. Only after *Novumbra* started the strike did the red larvae attempt to escape. The evasive movements were similar to those of the black larvae, but the red larvae appeared to remain motionless for a shorter period of time (this is a subjective evaluation) and

often attempted to swim slowly away if *Novumbra* followed. Such attempts to swim away were usually fatal.

The experiments were started with newly hatched larvae (6 days old) and continued at 1-day, and later 4-day intervals. Surviving larvae were never used more than once to avoid a learned escape response. The number of strikes *Novumbra* made divided into the number of larvae eaten gave a measure of the success of *Novumbra* once it had started a strike. This success ratio plotted against age (in days) gives some indication of the relative effectiveness of *Novumbra* as a predator on the two forms of sticklebacks, and also a measure of the changes that occur in the ability of growing stickleback larvae to elude *Novumbra*. The growth rates of both forms of sticklebacks were approximately equal. Both forms averaged 8 mm when first tested and reached a length of approximately 25 mm in 40 days.

The data summarized in Fig. 9 suggest that under laboratory conditions *Novumbra* is a more effective predator on red stickleback larvae than on black stickleback larvae, and that the time period over which it is an effective predator is longer in the case of red larvae. *Novumbra* appeared to show no preference for red larvae and made as many attempts to position itself for strikes at black larvae as for strikes at red larvae. The difference in the effectiveness of *Novumbra*

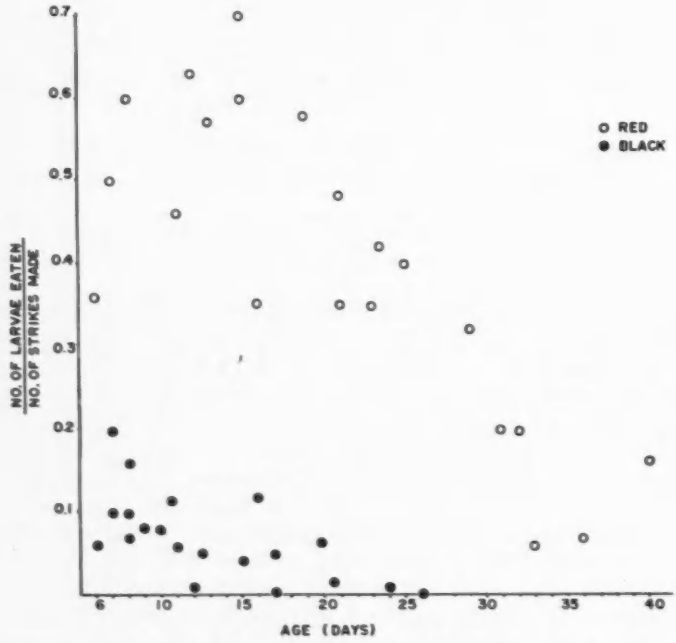

FIG. 9. Success of *Novumbra* feeding on native stickleback larvae of different ages.

predation on the two types of larvae appears to be due to the escape response outlined earlier. Since all of the larvae were laboratory reared, this difference in escape response is probably innate.

The difference in the success of *Novumbra* preying on the larvae of black and red sticklebacks reinforced the suggestion that in the Chehalis system the selective advantage of the black genotype is associated with predation by *Novumbra*. Since the predator is most effective on larvae immediately after they leave the nest, a possible explanation for the evolution of the black breeding colour is that *Novumbra* is differentially attracted to the territories of the more conspicuous brightly coloured males, and therefore, in areas where *Novumbra* is sympatric with sticklebacks, black males are at an advantage relative to red males.

Differential attraction experiment — This experiment was designed to test the hypothesis that *Novumbra* is differentially attracted to red males, and if so, that it is the colour that attracts *Novumbra*. Two of the 95-liter aquaria described in the mate selection experiment were used in this experiment. A black male was placed in the large chamber at one end of an aquarium and a red male at the other end. A *Novumbra* was then placed in the center partition and observations made through a one-way mirror. At 20-sec intervals for 30 min the orientation of *Novumbra* was recorded. The positions of the black and red males were reversed in the two aquaria to avoid any bias due to position. Each *Novumbra* was used twice and then discarded. The chi-square test was used to test the null hypothesis that *Novumbra* are not differentially attracted to red males.

In the first experiment there was no evidence of differential attraction on the part of *Novumbra* towards either type of nonbreeding male ($P > 0.5$, Table 10). In the next experiment males just coming into breeding condition were used. The black males were cryptically coloured and the red males were only beginning to develop faint breeding colours. All of the males built nests and showed territorial behaviour. These results are also summarized in Table 10, and again there is no evidence of attraction ($P > 0.75$). The third experiment involved males in breeding condition with fully developed nuptial colouration. All of the males built nests and showed territorial behaviour. This time *Novumbra* showed a strong tendency ($P < 0.005$, Table 10) to orient towards the red male.

Conclusions — *Novumbra* shows no preference for larvae of either red or black sticklebacks; however, there is an innate escape response in black larvae that makes them less susceptible to *Novumbra* predation, over a shorter period of time, than red larvae. *Novumbra* shows a strong tendency to orient toward red males relative to black males, and it is the male colour rather than the nest or the territorial behaviour that is responsible for this orientation.

TABLE 10. Differential attraction of *Novumbra* to red and black males.

Nonbreeding males (no colours)	
Black	Red
11	11
30	25
13	12
16	18
70	66
$\chi^2 = 0.1$	$P > 0.50$

Males with nests but colours only beginning to develop	
Black	Red
12	18
19	11
16	15
15	15
62	59
$\chi^2 = 0.025$	$P > 0.75$

Males with nests and in full nuptial colour	
Black	Red
10	20
5	25
13	17
5	21
9	26
5	25
51	134
$\chi^2 = 18.58$	$P < 0.005$

DISCUSSION

ORIGIN OF THE CHEHALIS BLACK STICKLEBACK

Over most of its circumboreal distribution the typical nuptial colour of male *Gasterosteus aculeatus* is red (Russia and Siberia, Berg, 1965; Japan, Okada, 1960; Europe, Seeley, 1886; eastern North America, Bigelow and Schroeder, 1953; Alaska, Evermann and Goldsborough, 1907). However, in Washington and British Columbia although populations are known in which the males are exclusively red (Little Campbell River, Hagen, 1967) there are other populations (Bonsall Creek, Sumas River, Samish River) in which the majority of males are red but a few individuals approach the complete black colour typical of the Chehalis populations. This suggests that the genetic basis for black nuptial colour may be present in many Pacific Northwest populations, but that the selective pressures and conditions necessary to fix this characteristic in populations are rare, or at least uncommon.

As a hypothesis it is suggested that originally the stickleback populations in the Chehalis system were similar to many existing stickleback populations in that the majority of males were red but some males tended towards black. In areas where *Novumbra* occurred sympatrically with such populations, persistent differential predation by *Novumbra* on the larvae of the reddest males provided the selective pressure necessary for the fixation of the black nuptial colour. A serious weakness in this hypothesis is that I have been unable to demonstrate that *Novumbra* is a predator on stickleback larvae in nature. In areas where *Novumbra* and black sticklebacks are sympatric I have never found identifiable traces of sticklebacks in *Novumbra* stomachs. However, the laboratory experiments indicate that *Novumbra* is not a particularly effective predator on black stickleback larvae, and with alternate prey available perhaps the absence of sticklebacks in *Novumbra* stomachs is not too damaging to the hypothesis. More critical are areas where *Novumbra* occurs sympatrically with red sticklebacks. Such areas are rare (to my knowledge) and usually either *Novumbra* or red males are present only in low numbers (e.g., Conner Creek between stations 2 and 3). Since data on predation by *Novumbra* on sticklebacks under field conditions are critical to hypothesis, perhaps transplant experiments could provide the necessary data.

Isolating Mechanisms

The available evidence suggests that the Chehalis black sticklebacks are genetically differentiated from normal red *G. aculeatus*. Tables 1, 2, and 3 indicate that there are heritable differences in gill-raker number, spine position, nuptial colour, and salinity tolerance. The only sympatric situation investigated was Conner Creek. The data summarized in Fig. 4, 5, and 6 suggest that in Conner Creek only the black genotype is found above station 4 (2.5 km from the mouth), and that below station 3 hybrids are abundant whereas the red genotype is confined to the first 0.5 km of the stream. The presence of natural hybrids in Conner Creek argues that reproductive isolation between the black and red genotypes is incomplete. However, there is no evidence of introgression above the hybrid zone, although the available data are not rigorous enough to completely disprove introgression. The best evidence against introgression is provided by gill-raker number (Fig. 5). The mean gill-raker number at station 3 is the lowest of any black population examined. Below station 3 hybrids are abundant. If introgression were occurring in Conner Creek the gill-raker number at station 3 should be higher (more like hybrids and the red genotype) than that of stations well above the hybrid zone. This reverse cline in gill-raker number strongly suggests that introgression is not occurring in Conner Creek and that genetic isolation is being maintained.

Normally reproductive isolating mechanisms are the primary factors restricting gene flow between divergent genomes. Grant (1963) suggests reproductive isolating mechanisms originate in two interdependent ways: as by-products of evolutionary divergence, and by reinforcement (through natural

selection) of partial isolating mechanisms. A number of partial isolating mechanisms are apparent in crosses between allopatric populations of black and red sticklebacks, and they probably reflect the basic genetic divergence between the two forms. These partial isolating mechanisms are the slight (about 5%) reduction in viability in crosses between black and red sticklebacks, the slight (about 5%) reduction in fertility of hybrid males, and the greater (about 50%) reduction in viability when the F_1 hybrids are backcrossed to the parental forms. In addition, hybrid males show a behavioural aberration that puts them at a severe reproductive disadvantage. Although they court normally and, at least in isolation, can spawn successfully with both red and black females, they do not show normal parental care. In particular, the nest fanning behaviour is reduced, and there is subsequently a high mortality in the egg clutches. All of the above factors probably act to reduce gene flow between the black and red genotypes in Conner Creek. They are all post-mating isolating mechanisms.

Dobzhansky (1937) argued that in sympatric situations, if hybridization occurs but the hybrids are at a selective disadvantage, selection will favour the reinforcement of pre-mating isolating mechanisms (mechanisms that prevent gamete wastage) and eventually hybridization will cease. In Conner Creek a hybrid zone exists, and the hybrids are probably at a selective disadvantage due to the partial isolating mechanisms listed earlier. If the contact between red and black sticklebacks in Conner Creek has existed for a number of generations, some reinforcement of pre-mating isolating mechanisms might be detectable.

Since breeding male sticklebacks court females and the male nuptial colour is known to function as an epigamic signal, female mate preference is a potential isolating mechanism. When females from allopatric red populations are given a choice between black and red males they show a strong preference for red males (Table 8, $P < 0.005$). I could detect no differences in courtship behaviour between red and black males, and red females respond readily to isolated black males. This suggests that the strong preference shown by red females in choice situations is due to the differences in male nuptial colour.

Females from allopatric black populations also show a preference ($P < 0.01$) for red males. In contrast, females from a black population above the hybrid zone in Conner Creek (station 4) show no preference ($P < 0.25$). The difference in female mate preference between these two populations of black females is significant ($P < 0.01$). If we look at this in terms of the number of mistakes (choosing the wrong genotype) the females make, then allopatric black females make 25% more mistakes than black females from the edge of the hybrid zone. The improved mate selection of females from station 4 could be interpreted as evidence for the reinforcement of mate selection, based on male nuptial colour, as an isolating mechanism where the two genotypes have come in contact. If this interpretation is correct it is worth noting that the change in male colour was selected for in allopatry (probably by predation),

and it is only in sympatry that it is taking on the secondary function of an isolating mechanism.

Taxonomic Status of the Chehalis Black Stickleback

I have deliberately avoided discussing the taxonomic status of the Chehalis black stickleback. The available data indicate that it is genetically differentiated from the normal red *G. aculeatus*, but whether it is sufficiently differentiated to warrant specific recognition is open to argument. Miller and Hubbs (1969) in reviewing the species problem in *Gasterosteus* argue that such instances (where hybridization occurs) are "borderline" and any decision becomes subjective and arbitrary. However, both Sibley (1961) and Bigelow (1965) point out that in instances where hybridization occurs decisions on specific status need not be arbitrary. In such instances, if it can be demonstrated that hybrids are at a selective disadvantage, the parental forms probably warrent specific status. By this criterion the Chehalis black sticklebacks are a species. However, *Gasterosteus* taxomony is totally confused, and there appears to be little point in adding another name to the present chaotic nomenclatorial problem.

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Effect of Feeding and of DDT on the Activity of Hepatic Glucose 6-Phosphate Dehydrogenase in Two Salmonids[1]

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The specific activity of liver glucose 6-phosphate dehydrogenase in yearling rainbow trout remained unchanged when the fish were starved for periods as long as 8 weeks and when starved animals were fed diets of various compositions. Injection of insulin concurrently with refeeding also failed to alter the specific activity of the enzyme in trout. The absence of a dietary or insulin influence on the teleost enzyme system is to be contrasted with studies in mammals in which the activity of hepatic glucose 6-P dehydrogenase was markedly stimulated after refeeding starved animals or injection of insulin.

Ingestion of the pesticide DDT by juvenile coho salmon or adult rainbow trout also had no effect on the specific activity of liver glucose 6-P dehydrogenase and DDT failed to inhibit the rainbow trout enzyme in vitro. These results also differ considerably from those found in higher animals.

These results suggest that the glucose 6-P dehydrogenase enzyme in teleosts may be under a different type of regulatory control from that found in mammals.

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INTRODUCTION

THE CONCENTRATIONS of certain hepatic enzymes in mammals are influenced markedly by dietary factors. For example, the specific activity of liver glucose 6-phosphate dehydrogenase (glucose 6-P dehydrogenase) and 6-phosphogluconate dehydrogenase decreases in rats during starvation and then increases sharply after refeeding with a diet containing large amounts of carbohydrate (Johnson et al., 1966; Tepperman and Tepperman, 1962; Young et al., 1964). The specific activity of liver glucose 6-P dehydrogenase also is decreased significantly in rats fed a ration containing the insecticide DDT (Tinsley, 1964, 1965).

Glucose 6-P dehydrogenase is one of the key enzymes in carbohydrate metabolism since it helps control the relative flow of glucose through the

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Embden-Meyerhof glycolytic pathway and the pentose cycle. In the dehydrogenation of glucose 6-phosphate by glucose 6-P dehydrogenase, NADPH is produced, which, in turn, is utilized for a number of biosynthetic processes and especially in the synthesis of fatty acids. Consequently, the level of glucose 6-P dehydrogenase in an organism may help to regulate lipogenesis (Cohn and Joseph, 1959) even though the amount of NADPH produced via the pentose cycle is insufficient to account for all fatty acid synthesis (Flatt and Ball, 1964). Alternatively, the level of lipogenesis or other activities that require NADPH may control the activity of glucose 6-P dehydrogenase (Tepperman and Tepperman, 1963).

The present investigation was initiated to determine the effects of starvation and of feeding on the activity of hepatic glucose 6-P dehydrogenase in fish. The effects of dietary DDT and the hormone insulin on this important enzyme also were examined in the teleost.

MATERIALS AND METHODS

Yearling rainbow trout (*Salmo gairdneri*) weighing approximately 120–500 g and fingerling coho salmon (*Oncorhynchus kisutch*) weighing 3–9 g were used in these investigations. Fish were maintained in water at 9 C and fed variations of a defined diet (Table 1) as described previously (Buhler et al., 1969). Fish were fed to satiation three times daily. Stock fish routinely received the control diet (diet A, Table 1).

In the first experiment a group of 100–350-g yearling rainbow trout were fasted and killed for removal of livers at 1, 2, 4, and 8 weeks. In a second experiment, trout of the same size were fasted for 1 week and then fed for 3 days on diets that were high (diet C, Table 1) or low (diet B) in carbohydrate or high in protein (diet D). On the 4th day the fish were killed for collection

TABLE 1. Compositions (g) of test diets.[a]

	Diets						
	A	B	C	D	E	F	G
Protein[b]	35	35	35	55	35	35	35
Dextrin	20	0	43	0	20	20	20
α-Cellulose	23	43	0	23	23	23	23
Technical DDT[c]	0	0	0	0	0.020	0	0
p,p'-DDT[c]	0	0	0	0	0	0.020	0.005
Total	200	200	200	200	200	200	200
Cal/100 g diet[d]	157	115	206	155	157	157	157

[a]Ingredients purchased from Nutritional Biochemical Corp., Cleveland, Ohio. Diets also contained 2 g cod liver oil containing 0.40 g α-tocopherol acetate; 8 g corn oil; 8 g vitamin supplement the same as that used by Nicolaides and Woodall (1962) with total weight adjusted to 8 g with α-cellulose containing 29% carboxymethylcellulose, Hi-Vis grade, Hercules Powder Co., Wilmington, Delaware; and 4 g of mineral mixture (Nicolaides and Woodall, 1962).

[b]Protein mixture contained 73 parts vitamin-free casein, 23 parts gelatin, 3 parts L-arginine and 1 part L-methionine.

[c]Added in corn oil solution. DDT obtained from City Chemical Co., New York, New York. Technical DDT contained 77.2% *p,p'*DDT.

[d]Calculations for energy content of the diets based on the assumption that in cal/g: fat = 9.00, protein = 4.00, and dextrin = 4.23 (Buhler and Halver, 1961).

of liver samples. In a third study one group of 160–400-g trout were fed the control diet (diet A) and a similar group were fed a diet containing 100 ppm *p,p'*-DDT (diet F) for 4 weeks. Individual liver samples were collected from control fish at 4 weeks and from the group fed DDT at 1, 2, and 4 weeks.

To determine the effect of the hormone insulin, a fourth experiment was carried out in which two groups of trout of approximately 200–500 g weight were fasted for 7 days and then injected intramuscularly with a suspension of protamine zinc insulin (U-40, Eli Lilly and Co., Indianapolis, Indiana) at a dose of 4 units per fish per day or about 13 units per kilogram. Preliminary studies had demonstrated that higher doses of insulin caused excessive mortalities in the trout. Insulin injections were given on the 8th and 9th day; one group of fish was allowed to continue their fast whereas a second group was force-fed twice daily on the 8th and 9th days with the control diet A expelled from a modified plastic syringe. Such feeding proved necessary since injection of insulin caused a loss of appetite by the trout. All groups of fish were then killed on the 10th day.

To study the effect of dietary DDT on another species, a fifth experiment was carried out with groups of fingerling coho salmon (average initial weight 3.7 g) fed either control diet or a ration containing technical or *p,p'*-DDT (diets E, F, G) for a period of 60 days. Diet consumption, growth rate, mortality, and DDT residue data have been presented previously for these animals (Buhler et al., 1969). The fish were killed by electrocution at the end of the feeding period and the livers from each group removed and then pooled for enzyme analysis.

To determine hepatic glucose 6-P dehydrogenase activity, samples of liver were weighed and then homogenized in two volumes of cold 0.154 M KCl in a Potter-Elvehjem homogenizer. Homogenates were centrifuged at 10,000 *g* for 20 min and the resulting supernatant solution diluted 10-fold with 0.154 M KCl for enzyme assay. The method of Kornberg and Horecker (1957) was used to measure the activity of glucose 6-P dehydrogenase along with an undetermined amount of 6-phosphogluconate dehydrogenase activity[3]. For the sake of convenience, however, this activity is reported in the text only as glucose 6-P dehydrogenase (Tepperman and Tepperman, 1962; Tinsley, 1964). Incubation mixtures contained in a final volume of 3.0 ml: 0.05 ml of diluted enzyme solution; 245 μmoles glycyl-glycine buffer,[4] *p*H 7.5; 1.25 μmoles glucose 6-phosphate; 2.5 μmoles $MgCl_2$; and 0.4 μmole NADP. The change in absorbancy at 340 mμ with respect to time was then followed at 25 C in a Beckman Model DB spectrophotometer. A molar absorbancy index of $6.22 \times 10^3\ cm^{-1} \times M^{-1}$ (Horecker and Kornberg, 1948) was employed to convert absorbancy changes to micromoles of NADPH.

The protein content of the 10,000 *g* supernatant fraction was determined by the colorimetric biuret procedure of Parvin et al. (1955). Enzyme specific activity was expressed as micromoles of NADPH formed per minute per gram of fresh liver or per milligram of protein. As no significant differences were noted in the activities of hepatic glucose 6-P dehydrogenase between adult male and female trout, these results were averaged without regard to sex.

RESULTS

Liver weights declined moderately in rainbow trout that had been fasted (Table 2) and the total activity of glucose 6-P dehydrogenase was reduced proportionally. However, the specific activity of the enzyme per gram of liver or per milligram of 10,000 *g* supernatant protein was not appreciably altered. In the rat, starvation is known to cause a marked reduction in both the specific

[3]Croston (1967) has shown that the relative specific activities of glucose 6-P dehydrogenase and 6-phosphogluconate dehydrogenase in rainbow trout liver homogenates are 39 ± 16 and 29 ± 15 μmoles NADPH/g liver per minute, respectively.

[4]All biochemicals employed in this investigation were products of the Sigma Chemical Company, St. Louis, Missouri.

and total activities of the liver enzyme (Glock and McLean, 1955; Tepperman and Tepperman, 1962).

Trout that were fasted and then fed a diet containing a high concentration of carbohydrate failed to show any increases in the specific activity of hepatic glucose 6-P dehydrogenase (Table 2). Feeding starved fish diets low in carbohydrate or high in protein also had little effect on enzyme activity. These results are in sharp contrast to those found in mammals where refeeding starved animals elicits dramatic increases in hepatic glucose 6-P dehydrogenase activity (Johnson et al., 1966; Fitch et al., 1959).

TABLE 2. Mean liver weights and hepatic glucose 6-P dehydrogenase specific activities in rainbow trout after starvation or refeeding starved animals diets of various compositions.[a]

Fish group	Weeks of fasting	Fish wt (g)	Liver wt (g)	NADPH (*μmoles/min*)	
				Per g liver	Per mg protein
Control (8)[b]	0	227±47[c]	2.15±0.54	25.9±3.9	0.231±0.068
Fasted (10)	1	217±86	1.79±0.75	24.4±10.5	0.214±0.104
" "	2	164±36	1.24±0.32	26.2±4.3	0.262±0.051
" "	4	220±68	1.63±0.83	23.2±7.6	0.183±0.048
" "	8	212±49	1.41±0.39	17.8±3.8	0.173±0.056
Refed diet high in carbohydrate (10)[d]	1	213±54	1.76±0.61	18.5±5.2	0.179±0.064
Refed diet low in carbohydrate (10)[d]	1	209±51	1.58±0.48	16.6±2.7	0.165±0.042
Refed diet high in protein (4)[d]	1	217±75	1.63±0.87	20.8±6.5	0.214±0.120

[a]Initial fish weight range 100–350 g.
[b]Numbers of fish.
[c]Standard deviation.
[d]Animals were fasted for 7 days, fed test diets for 3 days, and then killed on the following day.

The nutritional regulatory response to hepatic enzymes observed with mammals has been explained on the basis of insulin acting as the actual inducer for these enzymes (Weber and Convery, 1966). To test this hypothesis, rainbow trout were fasted and refed diet A with simultaneous administration of insulin. Treatment with insulin, however, caused no appreciable modification in the specific activity of liver glucose 6-P dehydrogenase (Table 3). Injection of insulin into starved fish or simultaneous refeeding with insulin injections over shorter or longer periods of time also failed to bring about any marked changes in the activity of the enzyme.

Feeding DDT to small salmon over a 60-day period caused a loss of up to 40% in relative liver size and a 2–22% fish mortality (Table 4). However, liver weights in rainbow trout remained essentially unchanged after exposure to DDT, and only one of the larger fish died during the 30-day feeding period (Table 4). These differences in response to DDT between coho salmon and

TABLE 3. Effect of insulin injection, fasting, and refeeding on mean liver weights and hepatic glucose 6-P dehydrogenase specific activities in rainbow trout.[a]

Fish group	Fish wt (g)	Liver wt (g)	NADPH (*μmoles/min*)	
			Per g liver	Per mg protein
Control (10)[b]	396±68[c]	4.36±0.58	24.3±1.5	0.193±0.014
Fasted[d] (10)	339±47	3.46±0.63	22.2±8.1	0.155±0.076
Refed[e] (10)	357±79	3.78±0.48	19.7±6.8	0.217±0.071
Refed + insulin (4 U/day)[f] (9)	336±103	4.10±0.89	16.8±4.9	0.158±0.030

[a]Initial fish weight range 200–500 g.
[b]Number of fish.
[c]Standard deviation.
[d]Fasted for 10 days.
[e]Fish were fasted for 7 days, force fed control diet A twice daily on days 8 and 9, and killed on day 10.
[f]Fish were fasted for 7 days, force fed control diet A twice daily on days 8 and 9, injected with insulin at 4 U/fish on days 8 and 9, and killed on day 10.

TABLE 4. Effects of feeding DDT on mean liver weights and hepatic glucose 6-P dehydrogenase specific activities in coho salmon and rainbow trout.

DDT fed (*ppm*)	Days of feeding	Final fish wt (g)	Liver wt (g)	NADPH (*μmoles/min*)	
				Per g liver	Per mg protein
		Coho salmon[a]			
0	60	7.4	0.12	17.7	0.198
25 (tech.)	60	8.6	0.13	18.6	0.215
100 (tech.)	60	6.9	0.071	17.5	0.207
100 (*p,p'*)	60	6.1	0.066	17.5	0.184
		Rainbow trout[b]			
0	28	318±43[c]	4.05±0.72	30.1±7.3	0.217±0.082
100 (*p,p'*)	7	293±91	4.09±1.57	29.1±8.7	0.268±0.072
100 (*p,p'*)	14	258±46	3.70±1.60	24.3±6.8	0.206±0.015
100 (*p,p'*)	28	343±100	3.97±1.96	31.5±9.4	0.225±0.058

[a]Analyses conducted on pooled samples from 45 fish. Cumulative mortalities at 60 days were 1% in controls and 2, 13, and 22%, respectively, in the DDT-fed salmon (Buhler et al., 1969). Average initial fish weight 3.7 g.
[b]Numbers of fish per mean were: control group 10, 1 week DDT fed 8, 2 weeks DDT fed 8, and 4 weeks DDT fed 6. One mortality occurred in the DDT-fed fish between 2 and 4 weeks. Initial fish weight range 160–400 g.
[c]Standard deviation.

rainbow trout presumably result from a size-related differential susceptibility to the pesticide (Buhler et al., 1969). Although ingested DDT either reduces or has no effect on the size of the liver in fish, it produces significant increases in liver size in the rat (Fitzhugh and Nelson, 1947; Tinsley, 1965).

DDT in the diets of either salmon or trout failed to alter the specific activity of hepatic glucose 6-P dehydrogenase (Table 4). Total liver enzyme activity remained unchanged in rainbow trout but activity was reduced in coho salmon paralleling the decrease in liver size in the latter species. Previous

studies with rats have demonstrated that ingested DDT causes a significant depression in the specific activity of hepatic glucose 6-P dehydrogenase and a less dramatic decrease in total enzyme activity (Tinsley, 1965).

Neither technical DDT nor *p,p'*-DDT inhibited trout liver glucose 6-P dehydrogenase in vitro (Table 5). These results differ from those with the rat in which addition of DDT was found to cause a significant reduction in the activity of the enzyme in vitro (Tinsley, 1964).

TABLE 5. In vitro effects of DDT on the specific activity of hepatic glucose 6-P dehydrogenase from rainbow trout.[a]

Triton X-100 (*mg per ml*)	DDT content (*μg per ml*)	NADPH (*μmoles/min*)	
		Per g liver	Per mg protein
0	0	30.3	0.293
2	0	32.9	0.318
2	2 (tech.)	32.1	0.312
2	20 (tech.)	30.6	0.300
2	20 (*p,p'*)	33.0	0.316

[a]Pooled enzyme from 3 yearling male trout with average weight 361 g. Incubation mixture contained 0.05 ml of diluted enzyme solution in a total volume of 3.0 ml.

DISCUSSION

The hepatic glucose 6-P dehydrogenase enzyme in teleosts does not appear to respond to dietary and hormonal factors in the same manner as its mammalian counterpart. Although the total activity of glucose 6-P dehydrogenase does decline proportional to the loss in liver weight in trout subjected to starvation, there was no diminution in enzyme specific activity. Fishes, therefore, appear to have a homeostatic mechanism that maintains the specific activity of liver glucose 6-P dehydrogenase at a relatively constant value as liver weight decreases during periods of prolonged fasting. Alternatively, changes in hepatic enzyme activity in fish may occur too slowly to be detected in the time periods employed in the present investigation.

Such enzyme regulatory processes might indeed tend to proceed less rapidly in teleosts than in mammals since the metabolic rates of fishes are normally only about one-twelfth to one-third those of the rat (Altman and Dittmer, 1968). Falkner (1961), for example, has concluded that blood glucose regulation in a marine teleost (*Cottus scorpius*) was qualitatively similar to that of mammals but that the reactions in fish occurred more slowly. Nevertheless, even with a reduced rate of enzyme regulation, some modification in the specific activity of hepatic glucose 6-P dehydrogenase probably would have been elicited after starvation of the trout for a period as long as 8 weeks.

Although ingestion of diets containing a high proportion of carbohydrate causes a remarkable increase in the activity of glucose 6-P dehydrogenase

in starved rats (Tepperman and Tepperman, 1962), no such response was observed in fasted trout. It is possible that the inability of carbohydrates to effect a change in the specific activity of the liver enzyme in fish may be related to the normally low carbohydrate content of the diet of fish and the fact that lipids probably represent the major dietary source of energy for most fishes (Mead and Kayama, 1967).

Insulin failed to bring about any change in the activity of liver glucose 6-P dehydrogenase in rainbow trout. Injection of insulin does produce a prompt reduction of blood glucose in fish (Phillips et al., 1948; Leibson and Plisetskaya, 1968) although the effect varies somewhat between different species (Hoar, 1957). The insulin control of blood glucose appears to be similar in fish and mammals (Leibson and Plisetskaya, 1968) but insulin-induced hypoglycemia is more long-lasting in the teleost. Although insulin promptly increases hepatic glucose 6-P dehydrogenase levels in higher vertebrates (Weber and Convery, 1966), the hormone apparently lacks this function in fish.

The failure of DDT to increase liver size or modify enzyme activity may be related to the inability of DDT to induce hepatic microsomal enzymes in fish (Buhler and Rasmusson, 1968). Possibly, the very high lipid content of fish (Buhler et al., 1969) may provide for increased storage of DDT and prevent the accumulation of the critical concentrations of DDT in the blood or the target organs such as are necessary for induction of hepatic enzymes. Chronic feeding studies with DDT in young salmon tend to support this conclusion since very little of ingested pesticide was found to be excreted (Buhler et al., 1969). Burden (1956) also has found that a species of fish containing a low proportion of lipid was more susceptible to DDT than one with a higher fat content. Failure of the liver glucose 6-P dehydrogenase to respond to DDT also may be related to the apparent absence of dietary or insulin control of this enzyme in fish.

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Bacteria Counts on Cod and Flounder Fillets Produced Commercially from Fish Frozen at Sea and Thawed in Water[1,2]

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Fillets of flounder (*Hippoglossoides platessoides*) and cod (*Gadus morhua*) produced in two commercial plants from uncut fish that had been frozen in blocks at sea, were free or nearly so of faecal coliforms and generally contained fewer indicator bacteria (all organisms in the coliform group; faecal coliforms) than fillets produced in the same plant from fish iced at sea. Coliforms were found in relatively small numbers on most fillets of thawed fish sampled on the conveyor leading from the mechanical skinner, on similarly prepared fillets sampled after trimming and portioning, and on fillets prepared from fish iced at sea and sampled immediately after skinning. The total plate count on the fillets of thawed fish at the point of trimming and portioning was small, suggesting that the fish frozen at sea carried a relatively low count of fish-spoiling organisms at time of freezing and thawing.

The results show that in processing blocks of gutted or gutted and headed fish it is practical to thaw in an immersion thawer at a temperature of 13–20 C while changing the water only infrequently, say every 12 hr, and to employ thawing runs of about 24 hr duration. During this time as many as five tankfuls of fish may be thawed. It is practical also to hold the fish thawed under these conditions in chilled potable water or in crushed ice for 1 or 2 days prior to processing.

It was shown that the sanitary aspects of the process can be assessed advantageously by observing the sanitary quality of the fillets, rather than that of the thawing water. The suitability of the method appeared to depend upon efficient washing of the thawed fish before it was put in buffer storage, or before it was filleted, or both. In one of the two plants sampled, large flumes were used and were satisfactory for delivering thawed, washed fish of high bacteriological and sanitary quality from buffer storage to the processing line. Here total plate and coliform counts either increased slightly or decreased slightly with prolonged use of the thawing water and of the boards used in cutting the fillets.

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INTRODUCTION

IN THE FUTURE, substantial quantities of flounder (*Hippoglossoides platessoides*) and cod (*Gadus morhua*) may be marketed as fillets or fillet portions after being processed from fish frozen at sea in blocks and later thawed ashore.

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We determined counts of fish-spoiling bacteria as well as counts of bacteria of interest to public health authorities on fillets of these fish to establish the sanitary quality to be expected in fillets produced commercially using a non-flowing, thawing water method. In one of the two plants in which the investigation was carried out, we obtained corresponding data on fillets of fish that had been iced at sea according to standard commercial practice and held unfrozen until ready for processing on the same line as that on which the thawed fish were cut.

The sanitary quality of fillets of fish iced at sea has been studied by others, notably Varga and Anderson (1968). However, the literature reports no comparable studies on fillets processed from fish frozen at sea.

Normally, the objective in determining sanitary quality is to ascertain the safety of a foodstuff from the public health standpoint. For this determination, specific members of the coliform and enterococcus groups of bacteria may be counted (Frobisher, 1949; Varga and Anderson, 1968). In the present work, we examined all samples for faecal coliforms. Any count of faecal coliforms is considered unacceptable in the production of fishery products processed under Canadian Government inspection. Although the determination of numbers of organisms in the coliform group is not of much use in routine sanitary inspection, such counts are of value in assessing the nature of a process as in the present instance where counts of coliforms were made in the thawing water and on the fillets.

MATERIALS AND METHODS

In the work reported here, we related total plate, coliform, and faecal coliform counts on the fillets (1) to the period of use of a single bath of thawing water or of two baths in succession in the same thawing tank; (2) to the conditions to which the fish were subjected between thawing and filleting; and (3) to use of fresh water and of sea water for conveying fillets along the processing line. The relationship examined under item 2 included storage of the thawed fish in ice or in ice-chilled fresh water prior to filleting and transfer of the fish directly from the thawer to the processing line.

Coliform counts on thawing water were made in field laboratories provided at the processing plants. Fish samples from one plant (plant A) were studied at the Technological Unit of the Fisheries Research Board of Canada at St. John's, Nfld., and those from the other (plant B) in about equal proportions at this laboratory and at the Department of Fisheries and Forestry of Canada Inspection Laboratory at St. John's, Nfld.

Raw Materials, Handling, and Processes

Particulars on the source of raw material, handling, and processing are given in Tables 1 and 2.

In plant A the sequence of handling and processing the fish removed from the cold storage was: thawing and immediate conveying, washing (pressure spray method), fluming, hand filleting, and machine skinning. In plant B, all fish were washed immediately after thawing, placed in chilled buffer storage before processing, and again washed while being flumed to the processing line.

The same conveyorized immersion thawer, constructed in stainless steel (Anon., 1967), and elevator-type fish washer (MacCallum et al., 1963) were used in the two plants.

The thawing tank had a capacity of 3500 Imp. gal; the weight ratio of water to fish in the tank fully charged with fish was 2.8:1. In the two plants, thawing temperatures (Table 1) were

TABLE 1. Raw materials and conditions for handling and thawing fish in the two plants.

Plant	Species	Storage temp (C)	Thawing temp (C)	Thawing time (hr)	Conveyor load (lb/hr)	No. of runs and, in parentheses, hours per run	
						Short	Long
A	Flounder, cod	−28	20	4¼	2000	6(12)	0
B	Flounder	−26	13–18	4½	1800	2(12)	1(22); 2(12)

Flounder (2–5 lb gutted weight) and cod (2–6 lb gutted, headed weight) caught on the Grand Bank were washed with sea water and frozen at sea within 2 hr of capture in 100-lb blocks in commercial vertical plate freezers; freezing time to −23 C was 4 hr. At sea the frozen fish were stored at −26 C; in processing plants A and B, at −28 or −26 C until thawing. In plant A the fish were thawed in short runs (a single thawing tank was filled with water only once); in plant B, in both short and long runs (in a long run the tank was filled twice). The same stainless steel thawing tank, having a capacity of over 8000 lb of fish, was used in the two plants.

maintained in the tank by using immersed tubular electric heaters; also, in plant B live steam was introduced directly into the thawing water. The water in the tank was not circulated while thawing was in progress. It was discarded after various periods of use: after 12 hr for "short" runs (single thawing tank filled with water only once, plant A and runs 2 and 3 in plant B, Table 2), at about the half way point (11.5 hr) and at the end (22 hr) of one "long" run (single thawing tank filled twice; lots 1-W-1 and 1-W-3, Table 2, and various sublots, Table 5), and after 6 and 12 hr for two other long runs (lots 4-W-1, 4-W-3, 5-W-1, and 5-W-3, Table 2, and various sublots, Table 5).

After each of the six runs in plant A the thawing tank was drained and all accessible surfaces above the stainless steel mesh conveyor belt washed with chlorinated (50 ppm) fresh water. Gross material below the conveyor was hosed to the drains. After four of these runs (yielding lots 1-1, 2-1, 5-1, and 6-1) in this plant, the whole apparatus was thoroughly washed with a detergent and rinsed with chlorinated fresh water. The last procedure was practiced also in plant B after each short run or the second stage of a long thawing run. A long run (plant B only) entailed discharging the first tank of water to waste after it had been used for several hours, hosing the tank and the load of fish with the conveyor stopped, then quickly refilling the tank, restarting the conveyor, and continuing with the production of thawed fish. With this method, the conveyor was stopped for about 45 min, this being considered an acceptable delay from the standpoint of production costs. With the alternative of removing all fish from the tank, lifting the belt, and scrubbing all exposed surfaces, washing would have cost more.

Before the start of each run and in refilling for the second part of a long run, the thawing tank was refilled with fresh water (plant A) or with the very slightly brackish (0.02% salt) water mixed with fresh potable water in the ratio of 1:2 (plant B), the residual chlorine being about 15 ppm in each instance.

The fish washer, fish delivery flumes, and the processing table flumes in plant A were supplied with fresh, chlorinated (12–15 ppm) tap water. In plant B, the washer and the fish delivery flumes were piped with chlorinated (12–15 ppm) sea water and the fillet (skins on) chute at the cutting table and the flume conveying the fillets to the trimming table were piped for both potable fresh water and chlorinated (12–15 ppm) sea water, the latter being used in production runs 1-W-1 and 1-W-3, the former in all other runs.

SAMPLING AND BACTERIOLOGICAL EXAMINATION

Samples of water for determining coliform counts were collected from the thawer in the two plants at the start, at one or more intermediate stages and at the end of each run or each

TABLE 2. Handling and processing of fish thawed under conditions described in Table 1.

Plant	Thawing run	Storage of thawed fish prior to processing: Lot sampled[a]	Holding medium[b]	Period of storage (*days*)	Processing[c]: Method of delivery to processing line	Boards used on processing line	Washing & treatment of boards
A	1 to 6	1-1, 2-1, 3-2, 4-2, 5-1, 6-1	Nil	Nil	Sublots were carried direct from the thawer allowing a continuous thawing–washing (in 12–15 ppm chlorinated tap water)–cutting process	16 for filleting & 6 for trimming (composition hard rubber)	During the noon hour the boards were hosed with chlorinated water. After each afternoon shift the boards were washed in chlorinated (50 ppm) sea water (plant A) or very slightly brackish (0.02% salt) water (plant B), soaked in disinfecting agent (Diversol), and rinsed in chlorinated water.
B	1	1-W-1	Chilled, potable water	1	Sublots stored over 1 or 2 nights were washed and flumed in chlorinated (12–15 ppm) sea water	18 for filleting (hard wood) & 8 for trimming (composition hard rubber)	
		1-W-3		1			
	2	2-W-1		1			
	3	3-W-1		2			
	4	4-W-1		1			
		4-W-3		1			
		5-W-1		1			
	5	5-W-3		1			
	2	2-I-1	Crushed ice	1			
	3	3-I-1		2			

[a]The first numeral in each code is the run number. The numeral 1 at the end of the code indicates that the tank was charged and thawing started with a clean, fully scrubbed tank filled with fresh, clean water; 2, that charging and thawing started with a flushed (not washed) tank refilled with fresh, clean water; 3, that the half run from which the thawed fish were sampled began with a flushed tank containing a full charge of partially thawed fish (left in the tank after the previously used thawing water was discharged) and a new charge of fresh, clean water. The W indicates storage of thawed fish before processing in ice-chilled potable fresh water (no measureable chlorine) in previously cleaned steel storage tanks (15,000 lb capacity); the I, storage of shallow layers of fish, separated by ice, in a box 5′×5′×2.5′. The ice used for storage was block-frozen in the plant using chlorinated (50 ppm) brackish (0.2% salt) water. It was crushed on site immediately before being applied to the fish.

[b]In plant B the thawed fish were stored in 3500–7000 lb (chilled water storage) or 700 lb (iced storage) sublots, each sublot corresponding to a specified period of use of the thawing water (Table 5), e.g., one sublot of fish from lot 1-W-1 was stored after the first tank of thawing water had been in use for 6–11¼ hr and two sublots from lot 1-W-3 after the second tank had been in use for 0–4 and 4–7 hr, respectively.

[c]One or two sublots of fish from each lot thawed in plant B were processed before noon and one after noon, there being two exceptions: fish from sublots of lots 2-I-1 and 3-I-1 were processed during afternoon shifts after completion of processing water-stored fish and rewashing the filleting and trimming boards with chlorinated (50 ppm) brackish water.

half run. The following technique was employed. Sterile, 6-oz screw-capped dilution bottles were used. For each examination, 9 sterile bottles were filled: 3 samples were drawn at the loading end of the thawing tank, 3 at the middle, and 3 at the discharge end. In sampling, the cap was removed from the bottle and the bottle was plunged neck down into the water to a position 6–8 inches below the surface in a manner to avoid contact with blocks of thawing fish and moved parallel to the surface in a continuing motion, always away from the sampler. The bottle was then removed and the cap replaced. Immediately after collection, the samples were examined at the field laboratory. The most probable number (MPN) technique was used for the enumeration of coliforms and results confirmed in tubes containing 2% brilliant green bile broth (American Public Health Association, 1960). The coliform counts are reported as numbers of organisms/100 ml water.

The fillets processed from thawed fish were sampled in both plants upon being discharged from the mechanical skinner and in plant B after trimming and cutting into 3–4-oz consumer portions. The samples were representative of fish removed from thawing water that had been used for various periods (Tables 3, 5). The tables show separate counts for fillets processed before and after noon, after use of the filleting boards for various periods. In each sampling, one or two fillets or portions equivalent to the fillets were aseptically placed in each of 6–8 multi-layered polyethylene and Saran pouches. The latter were heat-sealed and the fillets were frozen immediately in a horizontal plate freezer in which the temperature was lowered to −23 C in 1 hr, and cold-stored at −28 C until bacteriological counts (total plate, coliforms, faecal coliforms) were made. As well, fillets of fish iced aboard trawlers and processed in plant A were sampled upon discharge from the mechanical skinner and bacteria counts made (Table 4) to provide data for comparing bacteriological and sanitary quality with that of fillets of the thawed fish.

The fillet samples were allowed to semithaw at room temperature in their containers in preparation for making bacterial counts. A 100-g sample of fillet was aseptically transferred to a sterile blender jar with 300 g 0.1% peptone water and homogenized at high speed for 2 min. A 40-g aliquot of the homogenate was transferred aseptically to a dilution bottle containing 60 g 0.1% peptone water, resulting in a 1:10 dilution. Serial decimal dilutions were prepared in 0.1% peptone water and total viable counts made by the Standard Plate Count method (American Public Health Association, 1960) using 23 g Nutrient agar (containing beef extract 3 g; peptone 5 g; agar 15 g) in 1000 ml distilled water, *p*H 6.8, to which 5 g NaCl was added, or alternatively, Difco Plate Count agar (23.5 g in 1000 ml distilled water, *p*H 7.0). Incubation was at 25 C. The counts (organisms/gram fillet) reported are logarithmic averages. The 5:5:5 MPN series was used in the presumptive test for coliforms in lauryl tryptose broth. All gas-positive tubes determined after incubation at 35 ± 0.5 C (Inspection Laboratory) or at 37 ± 0.5 C (Technological Unit Laboratory) for 24 and 48 hr were confirmed for coliforms using brilliant green bile broth. Faecal coliforms were confirmed by separate loop transfers from the above positive tubes to EC Medium (Hajna and Perry, 1943) with separate incubations carried out in a water bath at 44.7 ± 0.2 C following the procedure laid down for raw fish examination in the Department of Fisheries and Forestry of Canada Manual (1968), and at 45.5 ± 0.1 C, the latter being a common temperature of incubation when EC Medium is used in the recovery of *Escherichia coli* from frozen foods (Fishbein and Surkiewicz, 1964). Coliforms and faecal coliforms are reported as numbers of organisms/100 g fillet.

RESULTS

PLANT A

Each thawing operation was shown to start with coliform-free water (Table 3). As thawing progressed, coliforms appeared in the water and the numbers of organisms increased with time. The average counts varied little between runs, none exceeding 843 when the water was used for 6 hr or less or 2886 when the water was used for an additional 6 hr.

TABLE 3. Average[a] total plate and indicator bacteria[b] counts on plant A skinned fillets of thawed flounder (runs 1–5, Table 2) and cod (run 6, Table 2) in relation to use and sanitary quality of thawing water and use of filleting boards. Samples were taken from the conveyor leading from the mechanical skinner.

Lot sampled[a]	Hours thawing water used	Coliforms in thawing water (*organisms/100 ml*)[d]	Hours filleting boards used after washing or hosing, or both		Coliforms on fillets (*organisms/100 g*)[c]	Total plate count on fillets (*organisms/g*)[c]
			Morning shift	Afternoon shift		
1-1	0	0				
	¼	345			–	–
	5.5	–	1		125	12,000
	6.5	–	2		178	22,000
	8.5	–		½	688	26,000
	9.0	2,588			–	–
2-1	0	0				
	4.5	–	¼		182	6,000
	5	584	½		–	15,000
	7	–	2½		734	15,000
	9	–		1	585	16,000
	11	2,588			–	–
3-2	0	0				
	5	–	½		14	9,000
	6	512	1½		82	11,000
	6.5	–	2		398	13,000
	7	–	2½		75	18,000
	7.5	–		¼	428	18,000
	8.5	–		½	560	17,000
	9	–		1	190	19,000
	12	2,400			–	–

4-2	0	0				
	4.5	193			–	–
	5.0	–	½		115	15,000
	6.0	465	1½		256	14,000
	8	–		½	1,095	21,000
	10	–		2½	544	26,000
	11	–		3½	444	36,000
	12	2,214			–	–
5-1	0	0				
	2.5	81			–	–
	5.5	843	1		–	8,000
	6.0	–	1½		–	14,000
	7.0	–	2½		–	21,000
	9.0	–		1	–	19,000
	10.0	–		2	–	24,000
	10.5	2,400			–	–
6-1	0	0				
	4	34			–	–
	4.5	–	¼		31	4,000
	5.5	–	1		65	5,000
	6	–	1½		141	11,000
	8	–		¼	165	20,000
	9	972			–	–
	10	–		2	225	26,000
	12	2,886		4	558	30,000

[a]The ranges of coliform counts for individual fillet samples from the various lots and the numbers of samples were: lot 1-1, 0–1100, n = 16; lot 2-1, 0–2400, n = 27; lot 3-2, 0–1100, n = 40; lot 4-2, 0–2400, n = 34; lot 6-1, 0–1100, n = 43.

[b]Tests were conducted for all members of the coliform group (coliforms) and for faecal coliforms. None of the latter were present.

[c]See footnote a, Table 2, for explanation of codes.

[d]Averages of 9 samples.

[e]Averages of 6–8 samples.

Average total plate (range 4000–15,000) and coliform (range 14–182) counts on fillets cut from the first samplings from the thawer were low (Table 3) and in most instances increased, but only moderately, as the thawing water and the filleting boards continued to be used. Generally, counts were higher following use of the cutting boards after the noon hour. Eighty-three percent of the samples examined were positive for coliforms. None of the 191 samples examined for faecal coliforms were positive.

For fillets from fish iced at sea (Table 4) the average total plate counts were slightly higher than for those from thawed fish. These counts showed a small rise following the noon hour. The range of average coliform counts was 470–628. All of the 58 samples of fillets from fish iced at sea were positive for coliforms and 9 (15.5%) were positive for faecal coliforms (range 9.1–150).

Plant B

(a) Flounder stored, after thawing, in ice-chilled potable fresh water

The first tank of thawing water had no coliform count initially (Table 5). As thawing progressed in the first tank of water, coliforms appeared and the numbers increased slowly throughout the thawing period. Counts reached average values of 29 at 4 hr, 150, 313, and 386 at 6 hr, 673 at 8 hr, 886 at 11½ hr, and 1320 and 2053 at 12 hr. On the three occasions on which the tank was flushed and refilled with water the counts of coliforms in the thawing water immediately after refilling were much lower (4, 19, and 26 for samples from lots 1-W-3, 4-W-3, and 5-W-3) than those in the water that had been discharged to waste. And the counts during thawing were not higher than when the tank was fully scrubbed: 254 organisms at 9.5 hr after refilling for sample from lots 1-W-3 and 142 and 161 at 6 hr for samples from lots 4-W-3 and 5-W-3. The reduction in counts in the water after flushing and refilling the tank was reflected in low average coliform and total plate counts on fillets of fish thawed after the tank was flushed, refilled, and again put into service.

Average total plate counts were low (range 3000–10,000) on fillets leaving the skinner but increased on fillets sampled after trimming and portioning, the daily ranges in counts in the second instance being 40,000–53,000; 120,000–170,000; 59,000–72,000; 49,000–120,000; and 54,000–94,000, respectively, for the 5 days production. The grand average was 84,000 ± 6000 (106 samples) for all fillets sampled at the end of the packing line at plant B.

For coliform counts, the same ranges were reported from the two laboratories for all fillets examined. The average counts in samplings from the skinners, 82% of which were positive for coliforms, ranged from 22 to 224; in those after trimming and portioning (all samples positive), from 340 to 4580. The counts on fillets sampled at the skinner were often lower than in corresponding lots of thawing water, whereas more often than not counts in the fillets at packing were higher than in the thawing water.

TABLE 4. Average[a] total plate and indicator bacteria[b] counts, in relation to use of filleting boards, for representative skinned fillets from 10,000-lb lots of flounder and cod iced aboard ship for 5 days and processed in plant A. Samples were taken from the conveyor leading from the mechanical skinner.

Species	Hours filleting boards used after washing or hosing, or both		Coliforms (*organisms/100 g*)	Faecal coliforms[c] (*organisms/100 g*)	Total plate count[c] (*organisms/g*)
	Morning shift	Afternoon shift			
Flounder	2		–	0	39,000
	4		–	0	57,000
		½	–	3.8	58,000
		1	–	5.2	56,000
		2		0	49,000
Cod	2		470	3.8	69,000
	3		–	0	62,000
	4½		–	6.0	59,000
		½		34.0	79,000

[a]The range of coliform counts for individual fillet samples was 230–1500 (the number of samples was 24), of the same order as found with the fillets of thawed fish (Table 3).

[b]Tests were conducted for all members of the coliform group (coliforms) and for faecal coliforms.

[c]Averages of 6–8 samples.

TABLE 5. Average total plate and indicator bacteria[a] counts on plant B skinned fillets of thawed flounder (runs 1–5, Table 2) in relation to use and sanitary quality of thawing water, conditions for post-thawing storage, filleting, and trimming, and the water used for fluming the fillets before skinning. Samples were taken from the conveyor leading from the mechanical skinner and after hand trimming and portioning.

Lot sampled[b]	Hours thawing water used	Coliforms in thawing water (*organisms/100 ml*)[c]	Hours filleting and trimming boards used after washing or hosing, or both		Fillets sampled at skinner[d]		Fillets sampled after hand trimming[d]	
			Morning shift	Afternoon shift	Coliforms per 100 g	Total plate count per g	Coliforms per 100 g	Total plate count per g
1-W-1[e]	0	0						
	6–11½	–	1½–2		47	5,000	462	40,000
	11½	886			–	–	–	–
1-W-3[e]	0	4						
	0–4	–	1¼–1⅜		30	3,000	340	44,000
	4–7	–	2¼–2¾		166	5,000	634	53,000
	9½	254			–	–	–	–
2-W-1	0	0						
	4	29			–	–	–	–
	4½–6	–	¾–1¼		70	10,000	806	170,000
	6–9	–	2¾–3¼		38	8,000	4,580	120,000
	8	673			–	–	–	–
	9–12	–		1½–2	100	6,000	2,560	120,000
	12	2,053			–	–	–	–
3-W-1[f]	0	0						
	4½–6	–	¾–1¼		224	10,000	600	72,000
	6	150			–	–	–	–
	6–9	–	2¾–3¼		120	5,000	383	70,000
	9–12	–		1½–2	58	4,000	587	59,000
	12	1,320			–	–	–	–

4-W-1	0	0						
	4½–6	–	¾–1¼		80	6,000	3,002	120,000
	6	313			–	–	–	–
4-W-3	0	19						
	0–3	–	2¾–3¼		88	5,000	520	98,000
	3–6	–		1½–2	64	3,000	358	49,000
	6	142			–	–	–	–
5-W-1	0	0						
	4½–6	–	¾–1¼		22	7,000	490	94,000
	6	386			–	–	–	–
5-W-3	0	26						
	0–3	–	2¾–3¼		204	5,000	662	54,000
	3–6	–		1½–2	161	4,000	608	77,000
	6	161			–	–	–	–
2-I-1	0	0						
	4	29			–	–	–	–
	6–6½	–		¼–½	66	10,000	446	25,000
	8	673			–	–	–	–
	11½–12	2,053		1–1¼	80	12,000	2,564	43,000
3-I-1[f]	0	0						
	6–6½	–		¼–½	178	7,000	328	75,000
	6	150			–	–	–	–
	11½–12	1,320		1–1¼	165	7,000	1,100	79,000

[a]Tests were conducted for all members of the coliform group (coliforms) and for faecal coliforms. There was acount (7 organisms/100 g) for faecal coliforms in only one sample, from lot 3-W-1 (fish removed from thawing water used 4½–6 hr).

[b]See footnote a, Table 2, for explanation of codes.

[c]Averages of 9 samples.

[d]Averages of 6 samples.

[e]Skins-on fillets of thawed samples from lots 1-W-1 and 1-W-3 were conveyed along the processing line in chlorinated (12–15 ppm) sea water. The fillets from all other lots were conveyed in potable tap water.

[f]Uncut, thawed fish stored over 2 nights before filleting. All other samples were stored over 1 night before filleting.

Where there was an increase in total plate and coliform counts in skinned or skinned and trimmed fillets of fish drawn from long-used thawing water or processed on boards used for long periods, the increase was small. In general, fewer organisms of both types were recorded in fillets from the thawed fish held 2 nights than in those from the fish held a single night. Counts on fillets of fish drawn from the thawer 4–7 hr after refilling the tank (samples from lot 1-W-3, Table 5) showed little difference from those from other fillets of fish removed 6–11½ hr after the first tank of thawing water was put into use (samples from lot 1-W-1). Only one of 176 samples examined was found to be positive for faecal coliforms, confirmation being obtained after incubation at the higher (45.5 ± 0.1 C) of the two temperatures. The use of chlorinated sea water for carrying the fillets processed from samples from lots 1-W-1 and 1-W-3, rather than the potable fresh water in which all other processed fillets were conveyed, resulted in ranges of total plate and coliform counts similar to those for fillets conveyed in fresh water. It is apparent that the thawing programs employed, permitting use of one or more tankfuls of water for definite periods, coupled with subsequent washing of the fish, result in low counts on the processed fillet.

(B) FLOUNDER STORED, AFTER THAWING, IN CRUSHED ICE

For most fillet samples of these thawed fish there were very similar total plate counts after skinning (range of average counts 7000–12,000). The counts on the trimmed fillets were also similar to one another, the range of average counts being 25,000–43,000 for the fillets produced from lot 2-I-1 and 75,000–79,000 for the fillets of fish from lot 3-I-1. There was little increase in average counts with extension of the time during which the same tank of thawing water was used, with continued use of the filleting boards and with raw material held 2 days rather than 1 in crushed ice.

Eighty-six percent of all fillets sampled at the skinner were positive for coliforms, the average counts ranging from 66 to 178. All samplings made after trimming and portioning were positive for coliforms, average counts ranging from 328–2564. There was only a small increase in coliform counts on the fillets in runs with extended use of the same tank of thawing water or filleting boards. Similarly, there was either no increase or only a small increase in counts on the fillets when the uncut, thawed fish was stored in ice for 2 days. No faecal coliforms were found on any of the samples.

DISCUSSION AND CONCLUSIONS

The method employed in this investigation, which consisted of determining bacterial counts on the fillets sampled at two positions on the processing line, proved useful for assessing the sanitary aspects of water thawing and allied operations, e.g., washing, storing, fluming, and processing.

It is probable that the frozen-at-sea blocks carried a relatively low count of fish-spoiling organisms at time of freezing and thawing and it is not surprising to find low counts on the filleted fish. Coliforms appeared in the thawing water

that at the start was free of these organisms. The counts in the water were generally lower in plant B than in plant A, possibly because in the former location the water temperature was lower or because live steam was introduced into the thawing water to provide some of the heat required for thawing the fish, or both.

Even when the thawing water is used as long as 12 hr, one may expect the fillets at the skinner to be free of faecal coliforms if the fish is washed well; however, after hand trimming and portioning, faecal coliforms may be found in the fillets at infrequent intervals (<1.0% incidence). Also, total plate and coliform counts may be expected to be higher after the fillets are hand trimmed, with the increase having no observable relation to the thawing or buffer storage operations per se.

Generally, the fillets of thawed fish fared well in comparison with fillets of iced trawler landings, as judged by total plate, coliform, and faecal coliform counts. Samplings made at the skinner from fish thawed in plant A had lower total plate counts than, and counts of coliforms similar to, those in fillets of fish iced at sea. Eighty-two (plant B) or 83% (plant A) of the samplings made at the skinner from fish frozen at sea were positive for coliforms as compared with 100% positive returns from fillets of fish iced at sea.

There was no evidence to indicate substantial adverse effect from extended use of thawing water or filleting boards as long as plant cleaning and supplies of wash water were adequate, nor were there adverse effects from storing the uncut, thawed fish in ice or in ice-chilled water for 2 days rather than 1 prior to processing, or from conveying the fillets in chlorinated sea water rather than in potable tap water. What might appear an anomaly in the case of plant B samples (where total plate counts on samples made at the skinner or after trimming sometimes decreased with use of thawing water and filleting boards) can be attributed to the particular situation existing in the plant with respect to washing the thawed fish. Once operations were well advanced after the start of the morning shift (say by 8:30 AM) the uncut, thawed fish remained in the chlorinated water in the flume leading to the filleting table much longer than did the fish directed to the flume at 8:00 AM. The fish reaching the filleters after 8:30 AM could have carried a much smaller bacteria load than did the 8:00 AM lots. This situation could have effected a reduction in the count on the cutting surfaces sufficient to lessen the transfer of bacteria to the fillets processed subsequently. With the samples from plant A no such effect would have been expected since all fish were in the washer and flumes for a similar period. At any rate, the net effect of the procedures employed in plant B was that the total plate counts on fillets sampled at the point of trimming and portioning were remarkably low.

From the standpoint of sanitary quality of the product, it is evidently practical to use the noncirculating, immersion-type thawer charged only infrequently with water to prepare sea-frozen fish for further processing. The desired result, the commercial production of skinned, trimmed fillets free or nearly so of faecal coliforms and having low coliform and total plate counts,

depends upon efficient washing of the thawed fish before it proceeds to intermediary chill storage or before it proceeds to the filleting line, or both. It appears feasible to use two baths of water in succession, without removing fish from the thawing tank at the time (say, after 12 hr thawing) the first thawing water is discharged to waste, and without costly and time-consuming washing of the tank at the midpoint of the thawing run. With this procedure, runs of upwards of 24 hr would be in order for the immersion water thawer, these to be followed by draining and complete cleaning of the whole thawer. The presence of coliforms in the thawing water, as encountered in such an operation, does not appear to be significant, since counts on the processed fillets were low. The work, therefore, indicates the importance of recognizing sanitary quality of the fillets as the main criterion for assessing thawing and associated plant practices.

The overflowing water immersion method (Lorentzen and Pettersen, 1966) might effect a higher sanitary quality in fillets than that reported here. However, immersion thawing using constantly overflowing water would have to effect definite improvement in sanitary quality to justify the cost of the extra water used. In comparing general thawing methods, rather than various water immersion methods, Lorentzen and Pettersen state that absolute sizes of bacterial and autolytic reductions in quality resulting from the thawing process are so small as to make it difficult to state the contribution of each. This supports the findings of MacCallum et al. (1967a, b, c) and suggests that the difference in sanitary quality between fillets produced commercially from fish thawed in overflowing water and those from fish thawed in nonflowing water could be very small.

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NOTES

Further Observations on the Response of Rainbow Trout, *Salmo gairdneri*, to Overhead Light

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KWAIN, WEN-HWA, AND HUGH R. MACCRIMMON. 1969. Further observations on the response of rainbow trout, *Salmo gairdneri*, to overhead light. J. Fish. Res. Bd. Canada 26: 3233–3237.

The response of rainbow trout (*Salmo gairdneri* Richardson) to overhead light changed with the growth of the fish. No response was evident until the age of 7 months, after which the response became more pronounced with age. Trout exhibited a significant preference for the darkest chamber when given a choice of five intensities of artificial light. Minimum light threshold for 10-month-old fish was between 0.01 and 0.005 lux. However, 24-month-old fish had a lower level of light threshold between 0.005 and 0.001 lux.

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PREVIOUS EXPERIMENTATION revealed that yearling but not fingerling rainbow trout, *Salmo gairdneri* Richardson, respond photonegatively by retreating under cover when exposed to certain overhead light intensities (MacCrimmon and Kwain, 1966). Similarly fingerling trout did not show bottom color selection, but a significant preference for the black bottom had developed by the age of 14 months (Kwain and MacCrimmon 1967, 1969).

The objective of this paper is to define more specifically the relation between photobehavior and age in rainbow trout, during the first 30 months of life.

Materials and methods — All trout used in this study were hatched in total darkness in the Department of Zoology, University of Guelph, Guelph, Ont., from eyed eggs provided by the United States Fish and Wildlife Service Hatchery at Manchester, Iowa.

Phototactic response was studied in a rectangular aquarium (92 × 35 × 25 cm) enclosed in a dark plastic canopy. Half of the aquarium was covered with a removable top, and the other half received illumination from a 100-w incandescent bulb suspended 1 m above the center of the aquarium. Light intensity on the water surface was 100 lux on the exposed half. A horizontal slit at the bottom of the vertical partition dividing the aquarium permitted the free movement of fish. Prior to experimentation, 20 fish were placed in the aquarium and held in total darkness for 30 min. On illumination, the distribution of fish was recorded at 10-min intervals for 100 min. The cover was alternated between halves at each 10-min interval.

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Light preference experiments were carried out in a 25 cm wide circular raceway with a diameter of 92 cm and equally divided into eight sectors, each equipped with a 100-w incandescent bulb. Intensities of light were established by 7.6-cm filters of X-ray plates with different exposures. The five intensities were set in a sequential arrangement to give a gradient from darkness to 100 lux and back to darkness. Gates were installed between chambers to give a bottom opening of 2.5–5 cm, depending on the size of fish studied. Water temperature was maintained at 11–12 C; dissolved oxygen at 8 ppm.

In studies on preferred light intensity, 20 fish were put in the raceway for 30 min under total darkness. The light was then turned on and, after 10 min, all gates were closed simultaneously. The number of fish in each chamber was counted. The mean of five observations in each trial was recorded. If a fish was between two chambers, it was considered to be in the chamber where its head was located. Only inexperienced fish were used in each of five trials. The same procedure was used for the minimum light threshold studies, only one light intensity being used for each trial.

Data were analyzed by the chi-square test and the results corrected by combining probabilities from the tests of significance (Fisher, 1954).

Phototaxis — Daily observations on the orientation of alevin held in the aquarium indicated no specific response to light. At first, the alevin lay on their sides on the bottom without reference to the light source. At about 7 days after hatching, they began to be sensitive to the light and showed a preference for all corners of the aquarium but no direction was indicated. However, by the time that the yolk sac had been absorbed (at about 14 days), the fry had become active and moved freely between the dark and light areas of the aquarium.

Fish tested at monthly intervals showed no preference for black or white during the first 6 months, after which time a negative phototaxis ($P < 0.001$) was evident and became more pronounced as the fish became older (Table 1). Fish between the ages of 14 and 30 months seldom ventured into the light while the experiment was in progress, but remained generally under the cover even as it was being alternated between the two ends of the aquarium.

TABLE 1. Influence of age on the distribution of rainbow trout in the covered and illuminated areas of the experimental tank. Data were the means of two lots with 10 observations each.

Age (*months*)	No. fish	No. fish in each area		*P*
		Illúminated (*100 lux*)	Covered	
1	20	10.5	9.5	0.99
2	20	9.7	10.3	0.78
3	20	9.3	10.7	0.89
4	20	10.3	9.7	0.94
5	20	10.1	9.9	0.84
6	20	10.9	9.1	0.94
7	20	4.8	15.2	0.001[a]
14	20	3.6	16.4	0.001[a]
30	20	1.6	18.4	0.001[a]

[a]Significant at 0.05 level.

Response to light intensity — Given a choice of five light intensities, from darkness to 100 lux, 10- and 24-month-old fish previously exposed to continuous light showed a significant preference ($P < 0.001$) for the unlighted chamber. No difference between the two ages of trout was apparent (Table 2A).

TABLE 2. Percentage of fish in the experiment of preferred light intensity and minimum light threshold. Data are the relative frequency of fish at each light intensity determined by the mean of five observations in each five trials of 20 fish.

A Preferred light intensity

Age (*months*)	Light intensity (*lux*) 100	5	0.1	0.02	0	*P*
10	0.2	1.6	1.4	15.4	81.4	0.001[a]
24	0.6	3.8	6.2	18.2	71.2	0.001[a]

B Minimum light threshold

Age (*months*)	Light intensity (*lux*)	% of fish: Test intensity	% of fish: Darkness	*P*
10	0.1 vs. darkness	24	76	0.001[a]
	0.5 vs. darkness	0	100	0.001[a]
	0.01 vs. darkness	10	90	0.001[a]
	0.005 vs. darkness	43	57	0.450
24	0.5 vs. darkness	23	77	0.001[a]
	0.01 vs. darkness	16	84	0.001[a]
	0.005 vs. darkness	33	67	0.030[a]
	0.001 vs. darkness	47	53	0.300

[a]Significant at 0.05 level.

Minimum light threshold — A difference was noted in minimum light thresholds between the two ages of trout tested (Table 2B). Trout at 10 months of age showed a significant preference for darkness when given the choice of an intensity of 0.01 lux and darkness. However, no significant preference was found in choice between an intensity of 0.005 lux and darkness ($P = 0.45$). A light intensity between 0.01 and 0.005 lux was considered, therefore, to be the minimum threshold of light for fish at that age.

In contrast, 24-month-old trout were capable of discriminating total darkness from an intensity of 0.005 lux, but not from 0.001 lux. It would seem therefore, that the light threshold was slightly lower for the older trout.

Discussion — The observation that the photobehavior of newly hatched rainbow trout changed with age is in agreement of the findings of Stuart (1953) for *Salmo salar* and *Salmo trutta*. The sequence of change in response to light was, firstly, a period of no perceptible response when first hatched; secondly, a photonegative response; and thirdly, a return to no perceptible response at a time when the yolk sac was nearly absorbed and an interest in

feeding had developed. Hoar (1958) observed phototaxis in the fry of Pacific salmon but gave no information on behavior prior to the free-swimming stage. Both Smith (1952) and Woodhead (1956) reported marked metabolic changes in rainbow trout alevin a few days prior to emergence and related them to the commencement of feeding.

Previous studies on phototaxis in rainbow trout showed no evidence of a photoresponse among fingerlings (5 months old), but yearling trout (24 months old) were found to be strongly photonegative (MacCrimmon and Kwain, 1966). Results of the present study support these earlier observations and, further, establish that negative phototaxis first becomes pronounced in rainbow trout at an age of about 7 months. The response remains highly significant at least to the age of 30 months. Similarly, bottom color selection by rainbow trout has been found to change with age at the same test light intensities (Kwain and MacCrimmon, 1967, 1969) and adds to the confirmation that the reaction to light changes with ontogeny (Ali, 1959; Hoar et al, 1957; Nikolsky, 1963, p. 44–56, 182).

Observations on the preferred light intensity of 10- and 24-month-old rainbow trout, at an age when a photoresponse was characteristic, showed a significant preference for the darkest area in the horizontal light gradient. Using the definition of Woodhead (1956) for limiting light intensity, the limiting intensity for these trout was less than 0.02 lux when introduced into the light gradient.

The lower threshold light value for the 24-month-old trout than for the 10-month-old trout indicates an increase in photo sensibility with age. This finding is in agreement with that of Woodhead (1957) who found the light threshold of brown trout for kinesis to be about 0.0005 lux and the sensitivity to increase with development, and is supported in general by the observations of Ali (1959), Brett and Groot (1963), and Blaxter (1966) on the visual acuity in fish.

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Further Analysis of Ration and Growth Relationship of Plaice (*Pleuronectes platessa*)

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Evidence is given that the average daily rations (R) and fortnightly growth increments (ΔW) of six weight groups of *Pleuronectes platessa* fed on *Mytilus edulis* are related as in the power equation $\pm(\Delta W - \Delta W_m) = \pm b(|R - R_m|)^B$. R_m is the daily ration associated with the growth increment (ΔW_m) at maximum growth efficiency; b and B are parameters. The power B has a mean value of about 0.5 and shows significant deviations from the mean especially in the case of smaller fish.

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Analysis of Dawes' (1930a, b) data on average daily rations (R) and fortnightly growth increments (ΔW) of *Pleuronectes platessa* fed on *Mytilus edulis* gave evidence that six weight groups of the fish had ration–growth increment relationships as $\Delta W = a \pm b\sqrt{|R - R_m|}$ (Rafail, 1968). R_m denotes the daily ration associated with maximum growth efficiency of a fish group; a and b are parameters specific for each group. It is probable that the power 0.5 in the expression $(|R - R_m|)^{0.5}$ is approximate. This expression may be more conveniently written as $(|R - R_m|)^B$, where B may take any value, probably less than one. Estimates of the parameter B are presented here.

Materials and methods — The parameter a refers to the growth increment associated with R_m (Rafail, 1968) and may be denoted by ΔW_m. Empirical graphs relating ration to growth increment may supply R_m and ΔW_m estimates.

$$\therefore (\Delta W - \Delta W_m) = \pm b\,(|R - R_m|)^B$$

or $$\pm \log (|\Delta W - \Delta W_m|) = \pm \log b \pm B \log (|R - R_m|)$$

or $$\pm \log (|\Delta W - \Delta W_m|) = \pm a \pm B \log (|R - R_m|).$$

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The logarithms are positive if $\Delta W > \Delta W_m$ and $R > R_m$, and vice versa. The last equation describes two straight lines. The negative line is not an extension of the positive one but is parallel to and displaced by -2α from the positive line. Each of the two lines was fitted independently by the least-squares method and the arithmetic means of $|\alpha|$ and $|B|$ were used as estimates for a group. The data corresponding to $R - R_m = 0$ were eliminated during the least square fittings. There were two methods for calculating Σy and Σxy with very different results, when a ration level was associated with positive as well as negative growth increments. The formulae were as follows:

$$\Sigma y = \sum_{1}^{n} \log (\Delta W - \Delta W_m) \text{ and } \Sigma xy = \sum_{1}^{n} \log (\Delta W - \Delta W_m) \log (R - R_m)$$

$$\Sigma y = n \log \left[\frac{\sum_{1}^{n} (\Delta W - \Delta W_m)}{n} \right] \text{ and } \Sigma xy = n \log \left[\frac{\sum_{1}^{n} (\Delta W - \Delta W_m)}{n} \right] \left[\log (R - R_m) \right].$$

The two methods provided different estimates of the parameters α and B. The parameter B for the 25–40-g group was estimated by the first method as 2.134, i.e., far from the reasonable 0.5 value (Rafail, 1968). The second method gave more reliable estimates than the first and was adopted although it is an approximate one.

Estimates and discussion — R_m and ΔW_m estimates from empirical graphs are shown in Table 1 as well as α, B, and 95% confidence limits for B. The advantage of the normal distribution of ΔW (Rafail, 1968) was taken into

TABLE 1. Estimates of parameters of regression formulae.

Parameter	Fish groups (g)					
	15–24.9	25–40	40.1–60	60.1–120	90.1–120	120.1–211
R_m	2.75	1.25	3.25	3.25	5.75	5.25
ΔW_m	6.25	2.00	5.20	4.50	7.30	7.30
α	0.526	0.180	0.324	0.411	0.565	0.068
B: mean	0.670	0.417	0.535	0.400	0.390	1.260
95% confidence limits	0.610	0.290	0.465	0.100	0.280	0.540
	0.730	0.550	0.605	0.700	0.500	1.980

consideration when testing for fitness of the regression formulae. The sum of squares of deviations from the regression $[\Sigma \{n_p(\bar{y}_p - Y_p)^2\}]$ was calculated from expected growth increments (Y_p) and mean values within arrays ($\bar{y}_p$). The mean squares of deviations from the regressions were compared with mean squares within arrays by the F-test (Fisher, 1958). There were nonsignificant departures from the six regression formulae (Table 2) and a nonsignificant aggregate test from the six tests ($\chi^2 = -2 \Sigma \log_e P = 17.904$, df = 12, $P = 0.1177$). The aggregate test from the six F-tests of significance of deviations from the regression formulae ($\Delta W = a \pm b\sqrt{|R - R_m|}$) (Rafail, 1968) was also nonsignificant ($\chi^2 = 19.817$, df = 12, $P = 0.07013$). The smaller chi-square and the larger P value in the first instance show a probable advantage

TABLE 2. F-tests of significance of deviations from regression formulae.[a]

Fish group (g)	Sum of squares								Mean square				
	Total	df	Between arrays	df	Within arrays	df	Deviation from regression	df	Within arrays	Deviation from regression	F	df	*P*
15–24.9	270.549	58	174.890	5	95.659	53	8.4455	4	1.8045	2.1114	1.17	4/53	0.3321
25–40	602.221	101	255.441	8	346.781	93	25.0187	7	3.729	3.574	1.043	93/7	0.5316
40.1–60	1023.340	94	515.896	9	507.445	85	23.4549	8	5.970	2.931	2.040	85/8	0.1429
60.1–90	1151.671	70	494.845	9	656.827	61	163.852	8	10.768	20.482	1.9021	8/61	0.07587
90.1–120	2738.055	121	1702.328	14	1035.727	107	171.372	13	9.6797	13.1825	1.362	13/107	0.1895
120.1–211	3320.887	72	2622.962	16	697.925	56	208.721	15	12.463	13.915	1.117	15/56	0.3568

[a]The total number of degrees of freedom was the total number of observations with homogeneous variance less three (two for R_m and ΔW_m estimated from the data).

of the formulae with the power B other than 0.5. The 95% confidence intervals for B do not exclude an approximate 0.5 value except for the 15–24.9-g group. The mean value of B for the first five groups is 0.48.

The plots of log ($E\Delta W/R$) vs. R, where $E\Delta W$ is the expected growth increment according to the formulae with power B, gave graphs similar to those plotted according to the formulae with the square root, except for the 120.1–211-g group. That is, as rations increase log ($E\Delta W/R$) increases irregularly to about R_m and then decreases in a straight line (Rafail, 1968). The 120.1–211-g group gave rise to a curved ascending limb with a decreasing slope as R approaches R_m and then an ascending straight line. This increasing growth efficiency at larger ration levels is not expected (Dawes, 1930b; Brody and Proctor, 1943; Kostitzin, 1939; Paloheimo and Dickie, 1966).

Maintenance diets, i.e., diets associated with no change of weights, were estimated at 0.226 and 0.972 g/day for 15–24.9- and 120.1–211-g groups respectively. Estimates for other groups were disregarded because they were extrapolations in the regions with heterogeneous ΔW variance (Rafail, 1968). The slope of log (maintenance ration) on log (mean weight taken as the central weight of a group), γ, was estimated at 0.6913. γ is the weight exponent in the expression ($T = \alpha W^{\gamma}$) relating total metabolism (T) to weight (W). γ was estimated at 0.73 using the formulae with the square root (Rafail, 1968), because of the high estimate (1.17) for the maintenance ration for the 120.1–211-g group. Therefore, the high B-estimate (1.26) for the 120.1–211-g group displaced the γ estimate to a larger extent from the expected 0.8 value (Winberg, 1956, 1961). It is, therefore, reasonable to disregard the high B-estimate for the 120.1–211-g group (1.26) despite the persistant high B value, i.e., 1.28 and 1.24 estimated from the negative and positive parts of the data respectively.

It may be concluded that 0.5 is an approximate value for the power B and that significant deviations are to be expected especially for the smaller fish.

The $R/\Delta W$ relationship may be used to arrive at a time/weight relationship. A fish may obtain an average constant daily ration, or a ration that is a function of fish weight ($R = k_1 W^{c_1}$, where k_1 and c_1 are constants) during t days. The initial and final weights may be denoted by W_0 and W_t respectively within a stanza. In the first instance there will be a constant daily increment ($\pm a$) and the linear relation ($W_t = W_0 \pm at$) seems to be satisfied in some instances. In the second instance,

$$dW/dt = \pm (|b^{1/B} k_1 W^{c_1} - b^{1/B} R_m|)^B + \Delta W_m,$$

$$\text{i.e., } dW/dt = \pm (|mW^{c_1} - n|)^B + q$$

where n, m, and q are constants.

Another expression may be obtained by assuming $R_m = k_2 W^{c_2}$ and $\Delta W_m = k_3 W^{c_3}$. Such relations may be justified when c_1 and c_2 attain small values so that R_m and ΔW_m vary within narrow limits. For example, assuming $R_m = 0.41 W^{0.5}$ and $\Delta W_m = 2.1 W^{0.25}$ for the 120.1–211-g group, $R_m = 4.51 - 5.95$, $\Delta W_m = 6.93 - 7.98$. The large mean square within arrays probably

permits the utilization of a range for R_m and ΔW_m because relatively large deviations from regression formulae will not affect the test of fitness of regression formulae. In fact, it is reasonable to assume that R_m and ΔW_m vary within narrow limits, according to fish weight, within stanzas.

$$\therefore dW/dt = \pm b\,(|k_1\,W^{c_1} - k_2\,W^{c_2}|)^B + k_3\,W^{c_3}$$

If $c_1B \approx c_2 \approx c_3B \approx \beta$, then $dW/dt = \pm W^{\beta}[b(|k_1 - k_2|)^B + k_3]$. Denoting the expression between brackets by the constant A, the time/weight relationship becomes $dW/dt = \pm A\,W^{\beta}$ within stanzas. Parker and Larkin (1959) regarded growth in fishes as a series of stanzas within each of which the growth rate is proportional to a constant multiplied by a fractional power of weight. Ursin (1967) considered growth in fishes as the difference between an anabolic term (absorbed food), which is a function of body size, and a catabolic term, which is a function of body size and absorbed food ($dW/dt = H\,W^m - k\,W^n$ where H, k, m, and n denote constants). It should be noted that growth relations, within stanzas, may not contradict equations like von Bertalanffy's, logistic, or Gompertz describing growth between stanzas.

Acknowledgments — Dr El-Sayed Mohamed Hassan made the useful suggestion that the power 0.5 in the expression $\Delta W = a \pm b\,(|R - R_m|)^{0.5}$ may be an approximate value of a parameter B.

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Fibrous and Cystic Lesions in the Ovaries of Aged Atlantic Cod (*Gadus morhua*): a Preliminary Report

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WILES, MICHAEL. 1969. Fibrous and cystic lesions in the ovaries of aged Atlantic cod (*Gadus morhua*): a preliminary report. J. Fish. Res. Bd. Canada 26: 3242–3246.

Ovarian stromal fibrosis occurred in four Atlantic cod (*Gadus morhua* L.) from the northeastern Gulf of St. Lawrence (49°07′N, 59°18′W) and off Fox Harbour, Labrador (52°18′N, 55°52′W), with accompanying cystic lesions in two specimens.

Externally the ovaries varied. Specimen 1 (115 cm fork length, age 18 years) possessed clear areas (0.5–1.5 mm) where the underlying stroma was relatively thin. Specimen 2 (107 cm, 19 years) possessed scattered cream or yellow nodules (<1 mm) and coalesced nodules (1.5–2.0 mm). Specimen 3 (118 cm, 19 years) had many colourless fluid-filled cysts (1.5–2.0 mm) and a few larger cysts (5.0 × 7.5–7.0 × 12.0 mm), the latter confined to the tapering posterior regions of the ovary. Specimen 4 (99 cm, 16 years) possessed large (up to 8 mm) multilocular cysts anteriorly.

Stromal fibrosis occurred to varying degrees in each specimen, containing predominantly fibrinoid as identified by Mallory's PAH, Weigert's fibrin test, and retention of a PAS-positive reaction after incubation in alkaline trypsin. Widespread degeneration of ovigerous lamellae occurred in specimens 3 and 4.

The condition of specimens 3 and 4 suggests involutional ovarian stromal fibrosis, but the endocrine studies necessary to confirm this opinion were not performed.

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THIS NOTE DESCRIBES the abnormal ovaries of four older Atlantic cod, *Gadus morhua* L., detected by internal examinations of about 2500 fish during routine sampling of commercial and research vessel catches. For several years workers at this laboratory have noted the rare occurrence of shrunken ovaries in older Atlantic cod from Newfoundland and Labrador waters, recording these on data sheets as "immature condition" (Fisheries Research Board of Canada, Biological Station, St. John's, Nfld., unpublished data). The present specimens were examined histologically and histochemically in an attempt to diagnose this condition. The observations are presented here in hope that they will stimulate further studies on abnormal ovaries of aged cod and investigation of endocrine glands of such diseased fish.

Materials and methods — Table 1 gives size, age, and capture data for the diseased specimens. Specimen 1 was caught by otter trawl in October 1966 by the Canadian research vessel *A. T. Cameron*, and specimens 2, 3, and 4 by commercial gillnets in August 1966.

Ovaries were fixed and stored in 4% formaldehyde immediately after removal from the fish and later embedded in paraplast or paraffin wax and sectioned at 8–10 μ. Sections were

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TABLE 1. Data on specimens of *Gadus morhua* with diseased ovaries.

Specimen no.	Fork length (*cm*)	Otolith age (*years*)	Depth of capture (*m*)	Locality of capture	Pathology
1	115	18	181	NE Gulf of St. Lawrence (49°07′N, 59°18′W)	Fibrosis[a]
2	107	19	101	Fox Harbour, Labrador (52°18′N, 55°52′W)	Fibrosis, nodules[b]
3	118	19	73	Fox Harbour, Labrador	Fibrosis, cysts[c]
4	99	16	73	Fox Harbour, Labrador	Fibrosis, multilocular cysts[c]

[a]Fibrinoid degeneration of ovarian fibrous connective tissue.
[b]Subperitoneal bodies embedded in ovarian connective tissue.
[c]Embedded in ovarian connective tissue.

stained by an Ehrlich's haematoxylin and 2% aqueous eosin technique devised for diseased human tissue at the General Hospital, St. John's, Nfld.; the Crooke-Russel modification of Mallory's method for connective tissue; Heidenhain's Azan; Mallory's phosphotungstic acid haematoxylin (PAH); Weigert's fibrin stain (WF); and the de Thomasi periodic acid Schiff technique (PAS).

To test for fibrosis in ovarian connective tissue (stroma) a method specific for fibrinoid was used because fibrinoid is characteristic of fibrosis of human tissues (Anderson and Scotti, 1968, p. 32–33, 806). Fibrinoid must be differentiated from fibrin and collagen, which are normal constituents of healthy fibrous connective tissues. Collagen is readily distinguished from fibrin and fibrinoid by Mallory's PAH technique, but fibrin and fibrinoid are indistinguishable by usual staining methods. However, Glynn and Loewi (1952) found that fibrinoid of human rheumatic fever is much more resistant to tryptic digestion than is fibrin, retaining its positive PAS reaction after such treatment, whereas fibrin becomes PAS-negative. Thus, to differentiate fibrin from fibrinoid some sections of each specimen were treated with 0.1% trypsin in a phosphate buffer of *p*H 8 at 37 C for 3 hr and then stained by the PAS method.

Observations — On dissection, the ovaries appeared excessively shrunken and withered to varying degrees when compared to normal spent female cod in the 16–19 year age-group. Clear areas, nodules, or cysts were visible in the ovarian wall; such inclusions are not typical of aged Atlantic cod.

Specimen 1 (Table 1) possessed a relatively flaccid fibrous ovarian wall marked by clearer, thinner areas 0.5–1.5 mm in diameter where the ovarian stroma was much thinner (Fig. 1). Microscopically, the clearer areas appeared as spaces in the stroma, lying just under the peritoneal membrane forming the external boundary of the space. Spaces were occupied by degenerated or necrotic tissue containing nuclear material but no cellular organization, and were lined on three sides by cells with strongly basophilic nuclei. Ovigerous elements in most regions of the gonad were reduced to a narrow zone of somewhat degenerate cells arranged in lamellae. These observations suggest fibrosis of the ovarian stroma with accompanying early cystic degeneration. In comparison, a section through a normal spent ovary (Fig. 2) shows the outer membrane, relatively narrow stromal zone, and ovigerous elements disposed in a well-developed lamellar arrangement.

The ovary of specimen 2 (Table 1) was externally marked by many tough, cream or yellow nodules, usually less than 1 mm in diameter, but mostly coalesced to form larger nodules about 1.5 mm across. Anteriorly, nodules were larger (1.5–2.0 mm) and more yellow. Histologically nodules were subperitoneal in position (Fig. 3), comprised densely packed and stained clusters of pleomorphic basophilic cells with large hyperdichromatic nuclei and scant cytoplasm (Fig. 4), and contained dense fibrils. Most fibrils had fibrinoid deposited on them, the rest being covered by collagen. In some areas nodules were surrounded on all sides by a band of collagen of varying width and outside this a mass of fibrinoid material, which also occurred in the underlying fibrous stroma (Fig. 5). In other areas nodules were surrounded by fibrils composed of fibrinoid and collagen. The stroma mostly consisted of a widely dispersed mass of spindle-shaped fibrous connective tissue cells, blood vessels, and glandular ducts. Predominantly fibrinoid material appeared to have replaced many of the germinal cells in the ovigerous lamellae. Pools of liquid material containing cell debris were present in the ovarian lumen. Surviving ovigerous elements were somewhat disorganized although the basic lamellar structure remained. These features are shown in Fig. 6.

The ovary of specimen 3 (Table 1) was markedly shrunken and its wall largely covered by colourless, fluid-filled cysts 1.5–2.0 mm in diameter (Fig. 7). A few larger cysts measuring from 5.0 × 7.5 to 7.0 × 12.0 mm occurred, but were confined to the tapering posterior extensions of the gonad. Cysts of all sizes possessed thin walls of fibrinoid material bounded on both sides by simple epithelium. Cyst contents were unstained, possibly due to loss of fluid during fixation or sectioning. Numerous fluid-filled cysts and cysts containing what may be degenerated ovigerous cells were also present in the fibrous stroma (Fig. 8). Some cysts protruded into the ovarian lumen. Fibrous lesions were extensive, being mainly spindle cell tissue peripherally but strongly fibrinoid internally (Fig. 9). Ovigerous tissue consisted of a few lamellar strands containing amorphous cells and an occasional necrotic oocyte. The ovarian lumen contained large pools of liquid material containing cell debris presumably derived from ovigerous cells. The presence of necrotic ovigerous cells in stromal cysts and the lumen suggests some degeneration of ovigerous lamellae had occurred.

The anterior third of the ovary of specimen 4 (Table 1) consisted entirely of large (up to 8 mm), multilocular fluid-filled cysts with walls composed of fibrinoid material bounded by simple epithelium and having unstained contents (Fig. 10). The presence of blood vessels in wider interlocular junctions suggests the cysts were embedded in remnants of connective tissue (Fig. 11). Simple cuboidal epithelium bounded cyst walls externally and interlocular junctions internally and externally (Fig. 11). Epithelial cells were stretched in many parts of the cyst walls and interlocular junctions.

The stroma immediately posterior to the zone of multilocular cysts consisted of apparently glandular germinal epithelial tissue, lining ductlike spaces and surrounded by fibrous connective tissue. Tall cells containing pale cyto-

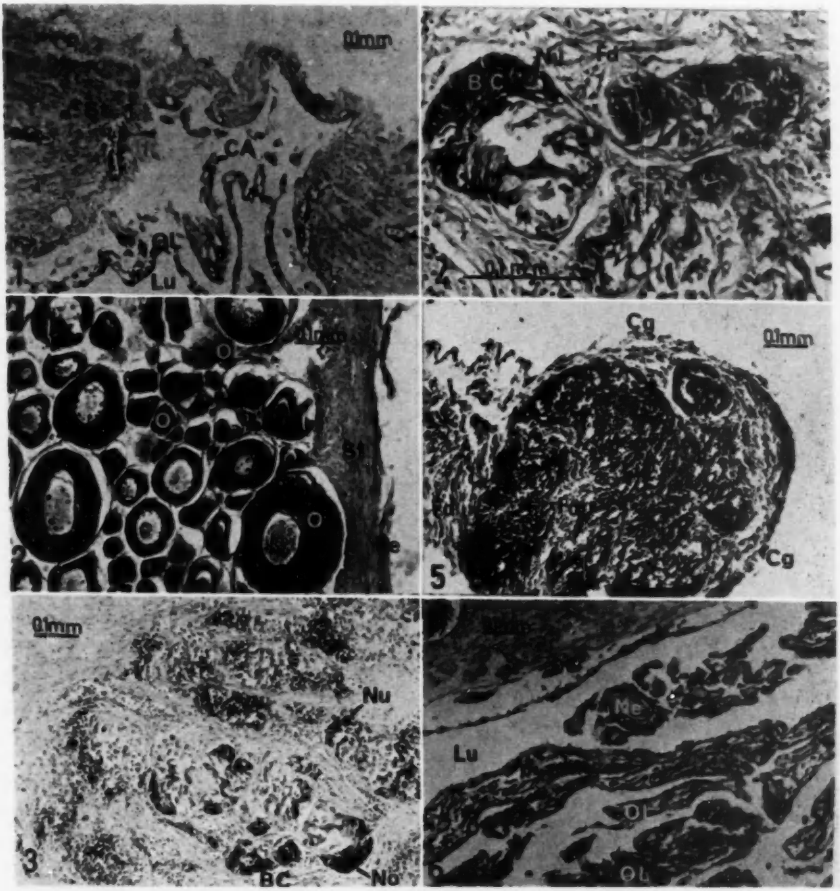

FIG. 1. Ovary of specimen 1 showing clearer, thinner areas in the stroma. Haematoxylin and eosin stain. Abbreviations used for figures: basophilic cells, BC; blood vessel, BV; cyst, C; clear thinner area, CA; collagen fibrils, Cg; unstained cyst contents, Co; degenerating ovigerous cells, DOC; epithelium lining ovarian lumen, Ep; fibrous connective tissue, FCT; fibrinoid, Fd; ovarian lumen, Lu; pools of necrotic tisue, Ne; nodule, No; large nucleus, Nu; primary and secondary oocytes, O; ovigerous lamellae, OL; peritoneal covering of gonad, Pe; stroma, St.

FIG. 2. Ovary of a normal spent female Atlantic cod for comparison with diseased specimens. Ovigerous cells are disposed in a lamellar arrangement. Haematoxylin and eosin stain.

FIG. 3. Subperitoneal nodules of specimen 2 composed of strongly stained basophilic cells with large nuclei. Haematoxylin and eosin stain.

FIG. 4. Nodules of Fig. 3 at higher power showing large irregularly shaped nuclei and presence in nodules of fibrils with fibrinoid or collagen deposited on them. Haematoxylin and eosin stain.

FIG. 5. Superficial nodule of specimen 2 bounded externally by collagen and an outer layer of fibrinoid extending into the underlying stroma. Mallory's phosphotungstic acid haematoxylin stain.

FIG. 6. Degenerated ovigerous lamellae of specimen 2 and pools of necrotic tissue in the ovarian lumen. Haematoxylin and eosin stain.

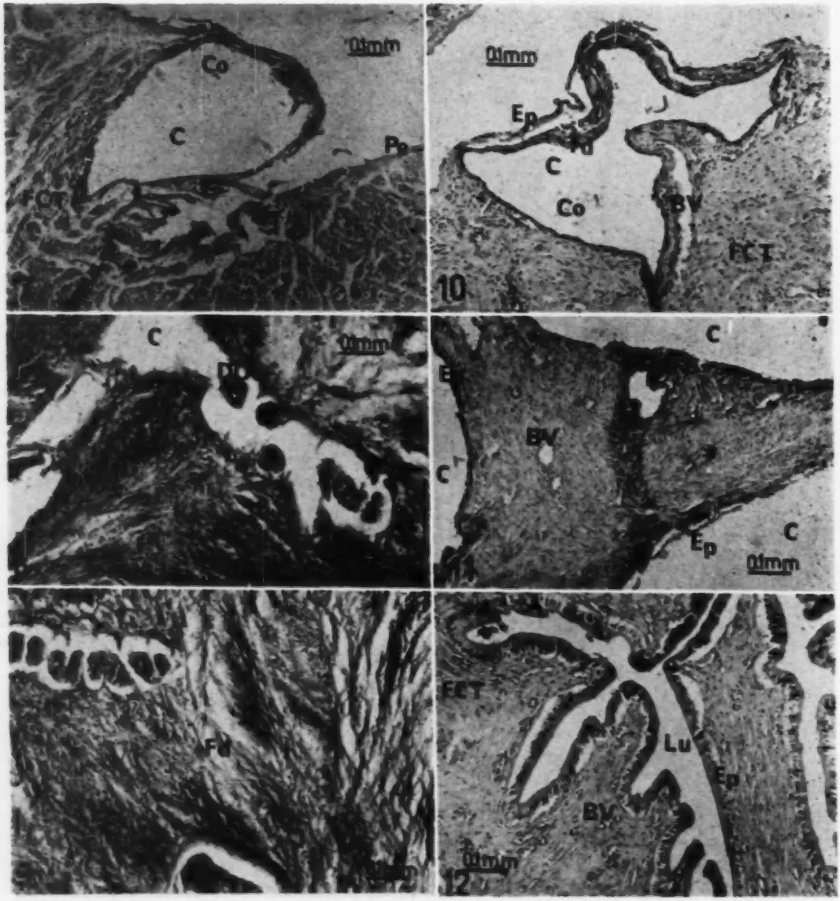

FIG. 7. Cyst in the ovarian wall of specimen 3 showing the fibrinoid walls and unstained contents. Haematoxylin and eosin stain.

FIG. 8. Intrastromal cysts of specimen 3 containing degenerated ovigerous cells. Haematoxylin and eosin stain.

FIG. 9. Ovarian stroma of specimen 3 showing extensive fibrosis composed of fibrinoid material. Haematoxylin and eosin stain.

FIG. 10. Multilocular cyst in the anterior third of the ovary of specimen 4. The walls are predominantly composed of fibrinoid and cyst contents are unstained. Haematoxylin and eosin stain.

FIG. 11. Interlocular junction between cysts in specimen 4 showing epithelial cyst lining and blood vessels in the junction. Haematoxylin and eosin stain.

FIG. 12. Zone of fibrosis in the ovary of specimen 4 showing epithelium of the ovarian lumen devoid of ovigerous lamellae. Note the many small blood vessels. Haematoxylin and eosin stain.

plasm and basal nuclei, and undifferentiated cuboidal cells with centrally placed nuclei constituted the modified epithelium. The highly vascularized ovarian wall and connective tissue contained cysts, which varied in size from 0.06 to 0.94 mm, but which were mostly less than 0.2 mm and confined to subperitoneal areas. Most posteriorly the ovarian wall was shrivelled and fibrous, containing cysts 1.0–1.5 mm in size. Many stromal cysts contained necrotic cells, which were possibly degenerating ovigerous cells.

Discussion — An extensive literature survey revealed few reports of ovarian diseases in marine fishes; see also reviews by Reichenbach-Klinke and Elkan (1965, p. 129–133, 139, 152–156, 168, 183–185) and Sindermann (1966). Ovarian cysts were reported in the angler *Lophius piscatorius* L. (Johnstone, 1913), and papillary cystadenoma in the ling *Molva molva* L. (Johnstone, 1915), but no account of similar diseases in Atlantic cod was found.

Histologically, the present abnormalities demonstrate varying degrees of fibrosis as defined for human tissues by Anderson and Scotti (1968, p. 805–806), with cyst formation in specimens 3 and 4 and possibly specimen 1. Whether the fibrous lesions were proliferative or cellular in nature, and thus neoplastic, is problematic. Fibrous repair tissue usually occurs in spent ovaries of older Atlantic cod, but not to the extent observed in the present specimens. Moreover, ample evidence of necrosis in ovigerous tissue, and absence of germinal cells from areas of cystic or fibrous lesions, suggest that excessive deterioration of germinal elements occurred. However, neoplasia seems improbable because fibrinoid, which is acellular and characteristic of degenerative rather than proliferative change, was detected, and proliferation of a single cell type was not demonstrated.

Since the specimens were relatively old, the hormonal imbalance of senility is a more likely cause of the fibrosis and cyst formation. Such abnormalities would then be classified as involutional ovarian stromal fibrosis. However, necropsies of the nongonadal endocrine organs, essential for investigation of ovarian involution, were not performed. In particular, examinations of hypophysis and thyroid are desirable because considerable evidence indicates that activity in these organs is necessary for maintenance of normal reproductive cycles in fishes (see review by Barrington, 1960), including *Gadus morhua* L. (Woodhead and Woodhead, 1965).

As the nature of the abnormalities is uncertain, it is unknown whether they represent different stages in the same disease or are unrelated pathologically.

Acknowledgments — This work was done at the Fisheries Research Board of Canada Biological Station, St. John's, Nfld., and the Department of Biology, Saint Mary's University, Halifax, N.S. I thank Dr A. W. May of the Station for collecting the diseased gonads from Labrador, Dr W. Onglingswan, pathologist, Institute of Pathology, Halifax, N.S., and Dr P. J. Markesteyn, pathologist, General Hospital, St. John's, Nfld., for their opinions of some of the prepared slides, and Dr Markesteyn for restaining some slides by a modified haematoxylin–eosin method developed for human tissues at his hospital. However, the responsibility for the diagnoses here presented is entirely my own.

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The Black Hagfish, *Eptatretus deani*, from British Columbia

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BOURNE, NEIL, AND D. E. MCALLISTER. 1969. The black hagfish, *Eptatretus deani*, from British Columbia. J. Fish. Res. Bd. Canada 26: 3246–3248.

The first two specimens of the black hagfish, *Eptatretus deani* (Evermann and Goldsborough), taken in British Columbia waters are reported and described.

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CLEMENS AND WILBY (1961) state that the range of the black hagfish, *Eptatretus deani* (Evermann and Goldsborough), family Myxinidae, is from California to Alaska in deep water but that no specimens have been recorded from British Columbia waters.

On August 5, 1965, a single specimen of black hagfish (Fig. 1), 51.0 cm long, was taken south of Cape St. James, the southern tip of the Queen Charlotte Islands. It was caught on a longline hook baited with squid (*Loligo opalescens* Berry) that was set in 165–455 m (90–250 fath) at 51°47′N, 130°58′30″W. In September 1968 a second specimen, 33.8 cm long, was taken in an Agassiz dredge off the west coast of Vancouver Island at 48°53.3′N, 126°40.0′W in 373 m (204 fath) from a mud and gravel bottom.

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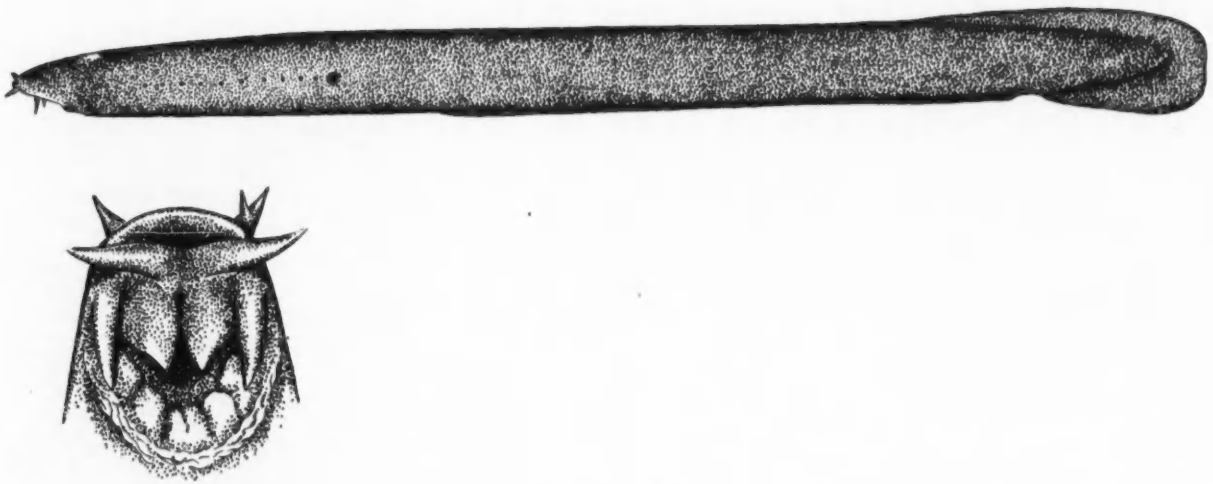

FIG. 1. Black hagfish, *Epiatretus deani* (Evermann and Goldsborough). Drawing made from specimen caught on August 5, 1965, which measured 51 cm total length. Illustration kindly prepared by Mr D. R. Harriott.

A description of the specimen, using the format in Clemens and Wilby, follows. Figures in parentheses give variation in non-British Columbia specimens. The body of this hagfish is elongate, cylindrical, and compressed posteriorly. The head is short; snout pointed, depressed; mouth a fleshy funnel; four horny plates on the floor of the mouth, the two outer ones with 12 teeth on the left-hand plate and 11–13 on the right, the two inner ones with 10 on the left and 10–11 on the right (11 + 11 and 10 + 10); one dorsal median tooth; nostril single large median, terminal, with opening into pharynx; barbels around mouth, 4, around nostril, 4 (sometimes one barbel branched); eyes not visible but usually marked by white areas. Gill pores, 11 (10–12), 10 on right side of smaller specimen, the distance from the first gill pore to the tip of the snout, 5.5–6.0 (5.4–6.6) times in total length; last pore enlarged. Length of branchial region from first to last pore, 6.3–6.7 (6.1–7.6). Skin: thin, smooth, loose. Anus large, near posterior end of body. Fin folds: dorsal (1), far back, median very low, continuous with caudal; ventral, median, very low, origin somewhat posterior to last gill pore, insertion at anus; caudal, broad, rounded. Mucus sacs numerous, about 78–79 in single series along each side of the body. Colour: prune-coloured. The very edge of the caudal and ventral fins light coloured. Total lengths: 33.8 and 51.0 cm (13.3 and 20.1 inches). Elsewhere known to 61 cm (24.0 inches).

The family Myxinidae is distinguished from other families by the flat pointed snout bearing 8 barbels, the small fleshy sucking funnel, the covered eyes, the 10–11 gill pores on each side, and the large anus very remote from the head. This species is distinguished from the Pacific hagfish (*Eptatretus stoutii* (Lockington)) by the smaller head; the distance from the head to the first gill opening enters 5.4–6.6 times in total length in *E. deani* compared with only 3.6–4.5 times in *E. stoutii*.

These specimens of black hagfish have been deposited in the National Museum of Natural Sciences, National Museums of Canada, Ottawa, catalogue numbers NMC65-317 and NMC68-383.

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Larval Swordfish (*Xiphias gladius*) from Three Localities in the Western Atlantic

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TIBBO, S. N., AND L. M. LAUZIER. 1969. Larval swordfish (*Xiphias gladius*) from three localities in the western Atlantic. J. Fish. Res. Bd. Canada 26: 3248–3251.

In February 1965, 47 larval swordfish were caught in three regions of the western North Atlantic: near Cape Hatteras, N.C.; off the east coast of Florida; and near the Virgin Islands. The captures were made in waters where the ranges of both temperature (23.4–25.6 C) and salinity (35.81–36.36‰) were small. The data support the conclusions of other workers that swordfish spawn in an area west of the Straits of Florida and in the most southern part of the Sargasso Sea.

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DURING FEBRUARY 1965, a study of larval swordfish was carried out in an area between Cape Hatteras, N.C., and the eastern part of the Caribbean Sea. The study area included the western Sargasso Sea, the Antilles Current, and the Florida Current–Gulf Stream system from Grand Bahama to Cape Hatteras. Hydrographic data collections were included in the program to discover temperature and salinity conditions where larval swordfish occur. The ship used was the CSS *Hudson*, a large (4800-ton displacement) oceanographic research vessel on loan from the Bedford Institute, Dartmouth, N.S.

Methods — Plankton collections were made at 36 stations (Fig. 1). Altogether there were 162 tows made with eight types of plankton nets. Three types of net (Neuston, lobster, and herring), which differed chiefly in size of opening, were towed at the surface. Deep tows to 500 m were made with 1- and 2-m nets, Icelandic plankton samplers, and Gulf III and Gulf V high-speed nets. Towing speeds varied from 2 to 5 knots, depending on both the type of net and the weather conditions at the time of the tow.

Oceanographic observations (temperatures, salinities, and dissolved oxygen contents) from the surface to 700 m were made at all plankton stations. Continuous surface temperature recordings were made over most of the cruise track.

Results and discussion — Larval swordfish were taken in three general areas: off Cape Hatteras, N.C.; off the east coast of Florida: and near the Virgin Islands (Table 1, Fig. 1). All but two of the larvae were taken in surface

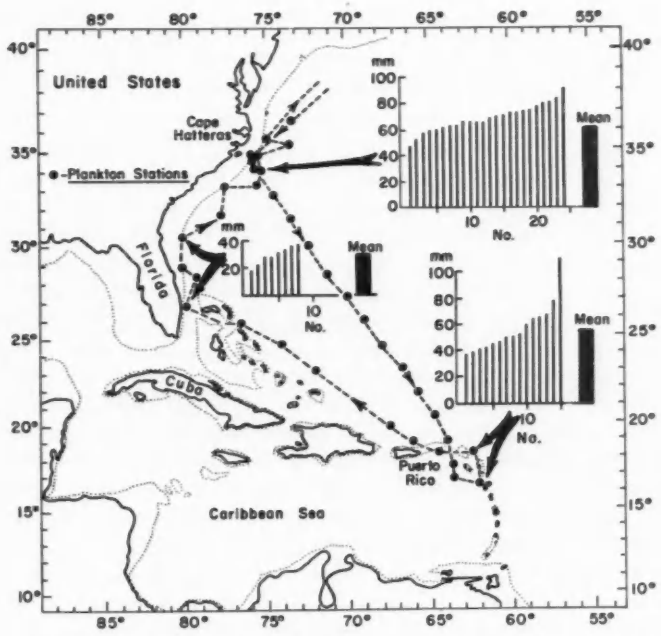

FIG. 1. Station locations, cruise track, numbers, size ranges, and mean lengths of swordfish larvae.

nets. The exceptions were taken in 1-m nets that were towed obliquely from a depth of 20 m to the surface, and hence may also have been captured at the surface.

TABLE 1. Larval swordfish captures during CSS *Hudson* cruise, February 1965.

Area	Station	Position		Temp (C)	Salinity (‰)	No. larvae	Size range (*total length in mm*)
		Lat	Long				
Cape Hatteras	5[a]	34°10.3′ to 34 06.5	75°34.3′ to 75 19.0	23.4	36.31	24	48.1–91.7
Eastern Caribbean	16	18 57.0	63 52.5	24.6	36.25	1	65.9
"	17	17 28.0	63 30.0	25.3	36.00	1	45.0
"	19[a]	17 11.5 to 16 47.0	63 38.5 to 63 34.5	25.6	35.86	11	36.5–110.6
"	22	16 36.0	61 57.7	25.3	35.81	1	43.1
"	23	18 11.5	62 24.5	24.8	36.36	1	66.5
East Coast of Florida	30[a]	26 47.0 to 26 53.5	79 56.7 to 79 53.5	25.4	36.14	7	18.7–38.9
"	33	30 28.0	80 09.0	25.0	36.14	1	28.7

[a]The two positions given for each of stations 5, 19, and 30 are those computed respectively for the beginning of the oceanographic observations and the end of a series of several plankton tows. The single positions given for the other stations are those computed for the beginning of oceanographic observations after which plankton tows were normally taken while sailing slowly in the direction of next station.

The size range (total length) of all the larvae captured was from 18.7 to 110.6 mm, but there were important size differences between areas (Fig. 1). Those taken off the east coast of Florida were considerably smaller (average length 30.3 mm) than those taken in the Cape Hatteras and Virgin Islands areas (average length 59.9 and 56.8 mm, respectively). The specimens from the last two areas were much larger than those reported by Arata (1954) and Tåning (1955), but the size range for all the specimens was much less than that of Yabe et al. (1959).

The larval swordfish in our collections were captured only at locations where a wedge of high salinity occurred at intermediate depths, but not in each instance where these conditions existed. All of them (Table 1) were captured within relatively narrow ranges of surface temperature and salinity (23.4–25.6 C and 35.81–36.36‰ respectively). Captures occurred near steep horizontal gradients of temperature in the Florida Current and of salinity in the Virgin Islands area. The coolest water (23.4 C) in which larval swordfish were taken was off Cape Hatteras within the Gulf Stream system. There is undoubtedly a relationship between the occurrence of swordfish larvae and the distribution, interaction, and modification of water masses, but this is not completely understood and requires further study.

The sizes of the swordfish collected (Table 1, Fig. 1), the average of estimates of swordfish growth rates (Sanzo, 1922; Arata, 1954; Tåning, 1955; Yabe et al., 1959), and the directions and average speeds of surface currents in the area (Iselin, 1936; Sverdrup et al., 1942; Wüst, 1964; Fuglister, 1951) suggest that the larvae caught off the east coast of Florida and in the Cape Hatteras area were hatched in the southern Gulf of Mexico, possibly in the Yucatan Channel. Larvae taken near the Virgin Islands most probably originated in the southern-most part of the Sargasso Sea, possibly at the northern edge of the Equatorial Current. The sizes and growth rates suggest spawning from mid-December to mid-February.

Thus, our data support the conclusion of other investigators, especially Arata (1954) and Tåning (1955), that there are at least two spawning areas in the Atlantic: one west of the Straits of Florida, and the other in the most southern part of the southern Sargasso Sea. However, most of the larvae in our collections must have been hatched earlier than the maximum spawning periods (April–September and February–September) suggested by these investigators.

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Spawning Behavior of the Brook Lamprey, *Lampetra planeri*

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The spawning behavior of the brook lamprey, *Lampetra planeri* (Bloch), was observed and photographed at the Berry Creek Experimental Stream Laboratory near Corvallis, Oregon. Observations and photographs were made from an observation booth constructed adjacent to the stream bed of Berry Creek.

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AN UNUSUAL OPPORTUNITY to observe and photograph the spawning behavior of the brook lamprey, *Lampetra planeri* (Bloch), was presented during a study of salmonid behavior at the Berry Creek experimental stream near Corvallis, Oregon. An observation booth (Fig. 1, A and B) was constructed in 1965 to facilitate behavioral studies of stream-dwelling salmonids. The booth is approximately 17 × 4 × 7 ft deep. Two windows constructed of ½-inch laminated glass provide for observation of 8 ft of riffle and 8 ft of pool along the stream bed.

The spawning activities of the lampreys were observed between 10:00 AM and 5:00 PM on May 18, 1968. The spawning site was on the riffle near the upstream end of the observation window. Water velocities were approximately 2.3 ft per sec. The water depth was approximately 4 inches and the substrate consisted of mixed gravels and rubble ranging from approximately $\frac{1}{16}$ inch to 4 inches in diameter.

The nest was dug immediately downstream from a large stone to which the lampreys attached their oral discs. While attached to the stone the lampreys performed rapid undulations that resulted in the displacement of the gravel (Fig. 1C). The gravel was carried downstream by the water current. Usually only a single individual, either male or female, performed the digging movements at any one time. Nevertheless, both were observed digging simultaneously in one instance. Some of the stones were not removed from the nest by the digging movements. The lampreys grasped these stones with their oral discs and carried them from the nest. Stones were carried as far as 6 inches in all directions. The largest stone that was removed in this manner was approximately ¾ inch in diameter. The circular nest was approximately 4 inches across at its widest diameter and 3 inches deep at the center of the depression.

At an advanced stage of nest construction, the female attached her oral disc to a stone at the upstream side of the depression and positioned her abdo-

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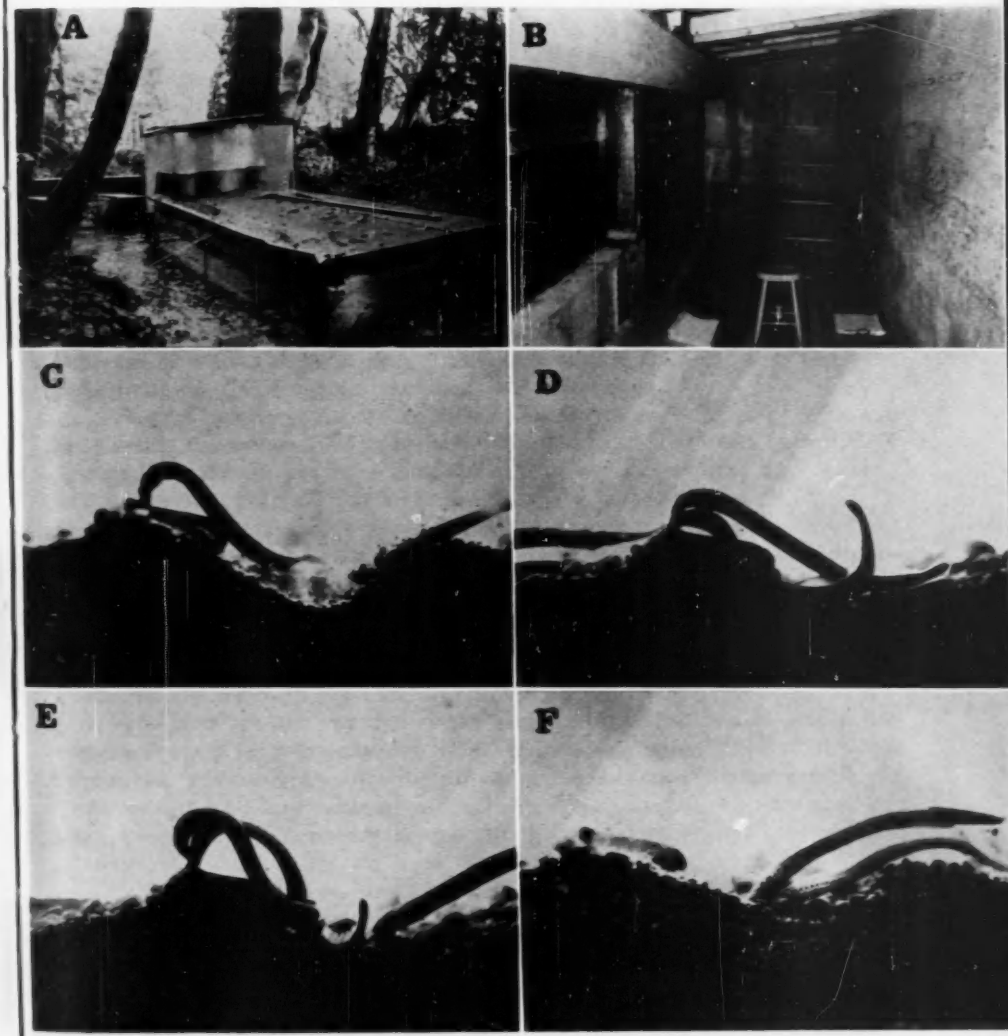

FIG. 1. An observation booth, (A) exterior and (B) interior, and activities by brook lamprey associated with spawning behavior: (C) "nest digging"; (D) male preparing to "clasp" female; (E) male "clasping" female; and (F) covering eggs.

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men over the depression. The male continued nest construction activities until he came into contact with the abdomen of the female. The male then moved his oral disc onto the dorsal surface of the female and forward to the anterior portion of the female's head (Fig. 1D). Occasionally, the female released her hold on the substrate, which caused the male to be dislodged. This apparent nonreceptivity was followed by further nest-building activity by both individuals. When receptive, the female remained attached to the substrate and the male retained his position. Both partners then arched the anterior portions of their bodies as the male coiled his tail around the female (Fig. 1E). In this position, rapid movements were made back and forth against the substrate. This activity resulted in egg and sperm extrusion into a "cloud" of small stones to which the eggs adhered and settled into the nest. The partners then separated and proceeded to move small stones over the newly deposited eggs (Fig. 1F). These covering movements were accomplished either by pushing stones with the anterior portion of their heads or by carrying stones into the depression with their oral discs. The spawning and covering activities were repeated six times before the nest was abandoned.

Several times, egg deposition did not follow the spawning act. When egg deposition did occur, 10–12 eggs were deposited into the nest. Immediately before a successful spawning attempt a distinct swelling near the female's vent indicated that a group of eggs was ready to be released.

A second female was present near the spawning partners described above (Fig. 1E). A distinct band around the body of this female near the anterior dorsal fin indicated that she had been clasped by a male during the spawning act. The second female performed nest-digging movements in several areas but did not concentrate effort in any one area. On two occasions, the male attempted to spawn with the second female, but she was nonreceptive and immediately removed her oral disc from the substrate.

The nest constructed during the sequence described above was superimposed upon nests constructed by other spawning pairs. Some of the eggs from the previous spawnings were disturbed and carried downstream in the current. At least four nests were dug in this small area. It appears that this site presented the necessary stimuli for the reproductive activities of these lampreys.

The eggs hatched on May 27 and 28 or approximately 10 days after their deposition. Soon after hatching the larvae moved from view, possibly to avoid sunlight reflected from the observation window. The average water temperature throughout the incubation period was 12.3 C and ranged from 10.0 to 15.5 C.

The activities of *L. planeri* photographed at Berry Creek closely parallel the spawning activities of *Petromyzon fluviatilus* photographed in a filming aquarium by Hagelin (1959). Many other observations and reports of lamprey activity have been compiled and summarized by Breder and Rosen (1966).

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An Improved Extender for Freezing Atlantic Salmon Spermatozoa

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A solution of chemical composition based on that of seminal plasma was an effective extender for Atlantic salmon spermatozoa; semen diluted to 20 volumes could be maintained at 4 C in an inactive but potentially motile condition for several days. Propylene glycol at concentrations between 7.0 and 12.5% protected sperm cells against freeze–thaw damage. The addition of glycine or albumin to the basic extender containing 7–12.5% propylene glycol or 10% dimethyl sulphoxide provided an extender meriting further development for the cryopreservation of salmonid spermatozoa. Fertilities of 5–19% were achieved with 10 frozen sperm samples diluted with such extenders. For frozen samples a method of fertilization with simultaneous addition of water and sperm to the eggs is proposed.

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EXPERIMENTS DESCRIBED BY Hoyle and Idler (1968) and by Graybill and Horton (1969) indicate that salmonid sperm cells can be frozen and remain viable although, in both instances, their results were not consistent and reproducible. When semen and eggs of Atlantic salmon were available we continued our studies to define conditions necessary to freeze the sperm cells successfully. Two factors were examined: the efficacy of a synthetic seminal plasma as a sperm extender and the upper and lower limits of the concentration of propylene glycol as protective agent.

Materials and methods — A basic medium for use as a sperm extender was prepared so that the molar concentration of the principal cations, sodium, potassium, magnesium, and calcium, equalled those in salmon seminal plasma (Hwang and Idler, 1969). The major anion was chloride but the minor anions, sulphate, carbonate, and phosphate, were included at concentrations comparable to those in Cortland saline (Wolf, 1963). The compositions of the basic (Hfx #1) and modified extenders are listed in Table 1. The molar ratio of Na^+:K^+ found in seminal plasma was maintained for all extenders.

Two protective agents were used: propylene glycol (PG) and reagent grade dimethyl sulphoxide (DMSO) distilled in vacuo (Burdick and Jackson Laboratories, Muskegan, Mich.). Pro-

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pylene glycol was substituted for ethylene glycol (Hoyle and Idler, 1968) because it does not form toxic breakdown products. Dimethyl sulphoxide was used since earlier experiments indicated that, even upon prolonged contact, DMSO did not inactivate salmon sperm (Truscott et al., 1968).

For all tests sperm was collected either by the usual method of "stripping" the milt or by syringe. The extender containing protective agent was added to the semen slowly over a period of 1 hr. Diluted semen was held in open containers and was transferred to 1-ml glass vials immediately before freezing. The time lapse between the first dilution of sperm and the beginning of the freezing process was approximately 3 hr. All experiments were done in a cold laboratory at 3–4 C. Motility tests, incubation of eggs, and detection of fertilized eggs were done as described previously (Truscott et al., 1968). Motility was used as a criterion of viability for nonfrozen samples. Only preparations that showed cells with self-propelled, ebullient, and random motion were rated as motile. In the freeze–thaw preparations any activity of the cells could be described as passive; only an occasional cell in a few samples could be rated as truly motile. Two freezing rates were used but no effort was made to determine the ideal rate of freezing. Samples were frozen in sealed 1-ml glass ampoules in a Canalco freezing unit at 1 C/min to −30 C, then at 5 C/min to −80 C. The frozen samples were then transferred to liquid nitrogen storage. Some samples were frozen in liquid nitrogen vapour in the Cryenco freezer (Horton et al., 1967). The freezing rate under our conditions was approximately 10 C/min to −50 C; the frozen samples were then lowered into the liquid nitrogen for storage.

Results and discussion — Our definition of a good extender is one that will allow dilution of the cells without their activation on the theory that the activation of a salmon sperm cell is a once-only action and the cell cannot be reactivated. The basic solution Hfx #1 (Table 1) was found to be a suitable

TABLE 1. Chemical composition of extenders for freezing salmon sperm.

Component (*g/liter*)	Hfx #1	Hfx #10
Sodium chloride (NaCl)	5.16	6.04
Potassium chloride (KCl)	1.64	1.64
Calcium chloride ($CaCl_2$)	0.143	0.143
Sodium bicarbonate ($NaHCO_3$)	1.00	0.0
Sodium dihydrogen phosphate ($NaH_2PO_4 \cdot H_2O$)	0.410	0.0
Magnesium sulphate ($MgSO_4.7H_2O$)	0.223	0.223
Fructose	1.00	0.60
Glycine	0.0	6.00
*p*H	7.3	6.4
Osmolality (*mosmols/liter*)	226	295

Extender #15 = Hfx #1 + 0.05% bovine albumin (4 × crystallized; Nutritional Biochem.)
#16 = Hfx #1 + 0.05% bovine albumin + 0.03% dithiothreitol (Calbiochem, Los Angeles, Calif.)
#17 = Hfx #1 + 0.05% bovine albumin + 0.03% dithiothreitol + 2.5% lactose

extender in that fresh sperm cells could be diluted at least 20 times and stored at 4 C for 6 days and still be motile upon dilution with water. Dilution of the cells on a microscope slide with solution #1 revealed that a small percentage of the cells are activated by the solution. The addition of the protective agent, 10% PG, to sperm suspended in Hfx #1 decreased the percentage of motile cells visible on a microscope slide; levels of 20% PG completely inhibited cell

movement. The addition of 10% DMSO to cells extended in Hfx #1 did not adversely affect their motility. With both PG and DMSO, dilution of suspended cells with 20% sea water or distilled water activated the cells in the normal fashion.

Preliminary freezing experiments indicated that cells suspended in Hfx #1 containing less than 5% PG were not protected from freezing damage regardless of the freezing rate. Upon thawing, all cells were damaged and denaturation of protein was evident. The effect of higher levels of PG before and after freezing was examined by fertility tests. Sperm cells diluted four times in Hfx #1 and #10 containing 10, 20, and 30% propylene glycol were held at 4 C for 24 hr. Fertility tests were compared with the original sperm samples that were also 24 hr old. Results of unfrozen samples in Hfx #1 were inconclusive because the eggs used in this test were no good; control samples with fresh sperm gave less than 20% fertilization. In Hfx #10 the results can be summarized as follows: controls, 80% positive; in 10% PG, 72%; in 20% PG, 43%; and in 30% PG, none positive. Aliquots of the samples both in Hfx #1 and Hfx #10 were frozen at 1 C/min and also tested for fertility. All were negative except a sample of sperm cells in Hfx #10 containing 10% PG. This sample fertilized 6% of the eggs used in the test.

To confirm this positive result samples of fresh sperm were diluted four and nine times with Hfx #10 containing 7, 10, and 12.5% PG, and 10% DMSO, frozen at 1 C/min, transferred to liquid nitrogen, and stored for 10 days. A few preliminary tests on the effect of additives other than glycine to the basic extender were also examined for survival of sperm cells after the freeze–thaw process.

The results of fertility tests are listed in Table 2. For tests the vials were transferred directly from the liquid nitrogen to a water bath at 4 C and allowed to thaw as quickly as possible. Ice was not allowed to accumulate around the vial and thus insulate the sperm preparation from the surrounding water bath. When liquefaction of a sample was complete the vial was opened and the sperm cells added to the eggs immediately. Instead of the usual "dry" method of fertilization, approx 0.25 ml of the suspension of sperm cells was added simultaneously with 50 ml water. Five minutes later the eggs were washed extensively with water to remove all excess sperm, transferred to shallow dishes, and placed in the laboratory hatchery. This "wet "method of fertilization is not favoured by fish hatcheries and could explain the low fertilities (average 64%) obtained with the control samples. However, the "wet" method may have contributed to the success of this experiment; it was tried in the hope that dilution of the glycol in the extender with a relatively large volume of water would negate its inhibitory effect on the motility of surviving sperm cells.

Although the results of these experiments are far from conclusive, the use in further studies of extenders with ionic composition based on Hfx #1 would be justified. The results of both motility and fertility tests indicate that such an extender will allow greater dilution of sperm cells than extenders

TABLE 2. Viability of salmon sperm after freezing and frozen storage as measured by fertilization of fresh ova.

Sample[a]	Extender	Dilution of sperm/extender (*v/v*)	Freezing rate (*degrees C/min*)	% ova[b] fertilized
1	Control	–	Not frozen	72
2	Control	–	Not frozen	56
3	Hfx #10 + 7% PG	1:4	1 to −30 5 to −80	16
4	"	1:9	"	17
5	Hfx #10 + 10% PG	1:4	"	10
6	"	1:9	"	11
7	Hfx #10 + 12.5% PG	1:4	"	9
8	"	1:9	"	14
9	Hfx #10 + 10% DMSO	1:4	"	14
10	"	1:9	"	5
11	Hfx #15 + 10% DMSO	1:4	10 (N_2 vapor)	15
12	Hfx #16 + 10% DMSO	1:4	"	10
13	Hfx #17 + 10% DMSO	1:4	"	19

[a]Samples 1–10 stored in liquid nitrogen for 10 days. Samples 11–13 stored in liquid nitrogen for 21 days.
[b]Approximately 150 eggs per test.

used in earlier studies. The principal difference between the new extender and those used previously by ourselves (Hoyle and Idler, 1968) and others (Graybill and Horton, 1969) is the molar ratio $Na^+:K^+ = 4.7$. In our modified Cortland solution the ratio equalled 0.49; in Graybill and Horton's Extender 48 the ratio was 25. The protective action of glycine or albumin, or both, cannot be assessed since samples frozen in Hfx #1 without additives were not tested under the same conditions. Glycine was an essential component of the extender used in freezing cod spermatozoa (Mounib et al., 1968); this extender is hypertonic to salmon spermatozoa and gave negative fertility tests even without freezing. Dithiothreitol has been shown to protect enzyme systems containing sulfhydryl groups and thus susceptible to oxygen inactivation, e.g., ATP synthesis in tissue homogenates (Horn and Haugaard, 1966). However, enzymes present in intact cells are less susceptible to such inactivation and the results of our preliminary tests suggest that dithiothreitol did not contribute to the activity of the sperm cells after the freeze–thaw process.

The decrease in numbers of eggs fertilized after storage and ageing of the sperm cells (Truscott et al., 1968; Withler and Morley, 1968) indicates that dead cells may interfere with the action of the living cells. The concentration of sperm cells in the semen of Atlantic salmon ranged from 12×10^9 to 30×10^9 cells/ml (unpublished data); similar concentrations have been reported for other salmonid species (Horton et al., 1967). Thus in our fertility tests even if only 0.1% of the sperm cells are viable, the live sperm cells will outnumber the eggs by at least several thousand to one.

The problem of defining the conditions necessary to successfully freeze salmon spermatozoa is complicated by the failure of a simple test, such as motility, to correlate with the crucial test, fertility. Although fresh sperm does give high motility and fertility rates, the positive results in this experiment were given by sperm samples showing little or no motility. Actually such behavior is not confined to fish sperm; mammalian spermatozoa of low motility after temperature shock have retained their reproductive capacity (Sherman, 1964). Again it could be a question of numbers. With a microscope the number of cells visible in a field is necessarily limited and cells are only motile for a matter of minutes. It is possible that with extremely low survival rates motile cells cannot be observed. Unless higher survival rates of sperm cells after the freeze–thaw process are achieved, further studies should be directed towards the development of a method of fertilizing the eggs which would overcome possible interference by inactive cells or a method of mechanically separating the dead from the living cells before their use.

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Infectious Pancreatic Necrosis Virus in Young Salmonids of the Canadian Maritime Provinces

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Infectious pancreatic necrosis virus was isolated from young salmonids, including Atlantic salmon (*Salmo salar*), in 9 of the 13 fish culture stations of the Canadian Maritime Provinces. The virus was isolated in tissue culture and identified serologically. There was no evidence of Viral Hemorrhagic Septicemia (Egtved disease).

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Outbreaks of a disease causing losses in brook trout (*Salvelinus fontinalis*) fingerlings in the eastern United States were investigated by Wood et al. (1955). Histopathological examination revealed that there was considerable destruction of the pancreatic tissue, and for this reason, together with the finding that the disease was transmissable by water, the condition was named "infectious pancreatic necrosis" (IPN). Wolf (1966) has reviewed the subsequent work that established the viral etiology of IPN and that characterized the responsible agent. Diagnosis of the disease (including detection and identification of the virus) and suggested measures for its control have been fully discussed by Wolf and Quimby (1967), and Wolf et al. (1968). This note reports the results of a survey conducted in early summer 1968 to determine the existence of IPN in the 13 fish hatcheries in the Canadian Maritime Provinces.

Methods — With only minor modifications, the procedures were those of Wolf et al. (1968).

Cell cultures. The RTG-2 cell line of Wolf and Quimby (1962) was used in this study.[2] Cells were routinely cultivated at 18 C in Eagle's Minimum Essential Medium with 10% fetal calf serum. Penicillin, streptomycin, and nystatin were added at concentrations of 100 units, 100 µcg, and 25 units per ml respectively.

Anti-IPN virus serum. Immune serum was prepared in rabbits using as antigen the supernatant fluid of first passage cultures of a lyophilized preparation of IPN virus (ATCC VR No. 299).[3] The antiserum was heated at 56 C for 30 min and then adsorbed on monolayers of RTG-2 cells to remove antibody to cellular antigens. Neither the antiserum thus treated nor the pre-immune serum of the same animals evoked any morphological change in RTG-2 cells. Both sera were stored at −18 C. Replicate titrations of the antiserum showed that a 1:3000 dilution in normal saline was the highest neutralizing dilution when 0.3 ml was mixed with an identical

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volume of antigen suspension containing approximately 10^3 tissue culture infectious doses — 50% end point ($TCID_{50}$) of virus.

Collection and processing of samples. Representative samples of brook trout were collected during the 3rd–5th weeks after commencement of feeding. Atlantic salmon at these sampling times were generally still in the sac-fry stage. The fish were transported on ice to the laboratory where they were kept at 4 C for 12–18 hr to await examination. The number of fish displacing approximately 3 ml of water (10–20 fish) were homogenized with nine parts of phosphate buffered saline (PBS). After centrifugation the supernatant fluid was further diluted with PBS to one-fiftieth of the original material and then passed through a 0.45-mμ Millipore filter.

Isolation and identification of virus. Six tubes of 4-day-old RTG-2 cells (in which the monolayers were almost confluent) were each inoculated with 0.1 ml of the test filtrate and incubated at 18 C. After equilibration, which followed the final tightening of the culture tube caps, the *p*H was in the range 7.4–7.8. Tubes not exhibiting cytopathic effect (CPE) were discarded after 2–3 weeks.

Where available, two tubes from each sample showing CPE were selected for use in the antiserum neutralization test performed as follows. Medium from these tubes was diluted with PBS to yield a virus suspension containing 10^3–10^4 $TCID_{50}$ in 0.3 ml. The neutralization mixture, composed of 0.3 ml of virus and 0.3 ml of the anti-IPN virus serum diluted 1:100 in normal saline, was incubated for at least 20 min at 18 C, after which 0.2 ml was added to a tube of 4-day-old RTG-2 cells. A 1:100 dilution of normal serum was substituted for immune serum as a control for each isolate. Periodically throughout the tests a suitable dilution of homologous antigen was used to monitor the continuing effectiveness of the antiserum. The inoculated cell sheets were incubated at 18 C and examined daily for CPE.

Results — In all, 70 samples were processed and half of them were found to harbour an agent capable of producing CPE in RTG-2 cells (Table 1). Neutralization tests with IPN-specific antiserum on each positive sample showed in every instance that the appearance of CPE was either delayed for a period of at least 2 days beyond that required for its appearance in the corresponding control tube or had failed to appear when the tube was discarded after 17 days. The serologically distinct VHS (Egtved) virus was thus not included among our isolates, although conditions were favourable for its cultivation (Wolf, 1966). No virus was isolated from samples obtained from the fish culture stations at Cardigan, Antigonish, Margaree, and Fredericton nor from a sample of wild fish from a lake near the Margaree station. The IPN virus was isolated, however, from wild fish recovered from a distribution tank in the water supply of the Florenceville station.

Discussion — M'Gonigle (1940) reported a disease (acute catarrhal enteritis) with symptoms identical to those describing IPN that affected artificially reared salmonid fingerlings in the region covered in the present survey. Fish pathologists have long considered that these two diseases were synonymous, but for lack of sufficient information this interesting question will remain unresolved.

The IPN virus is present in the majority of the fish hatcheries of the Maritime Provinces. We suspect, however, that some of our isolates may be antigenic variants of the strain used to produce the antiserum because their infectivity was delayed rather than inhibited in its presence. Failure to isolate the virus from samples of brook trout obtained from Antigonish, Margaree,

TABLE 1. The incidence of IPN virus in young salmonids raised in the Maritime hatcheries (1968).

Hatchery	Species	Week of systematic feeding	No. samples examined	No. samples[a] positive
Yarmouth	Brown[b]	4	2	2
	Rainbow[c]	Sac-fry	1	0
	Brook[d]	4	2	2
Kedjimkujik	Salmon[e]	"No. 2 fingerlings"	2	1
Mersey	Brook	4	3	3
	Brook	7	1	1
St. John	Brook	3	5	1
	Brown	3	1	0
	Brook	5	1	1
Coldbrook	Brook	5	8	5
	Brook	6	2	0
Cardigan	Brook	5	7	0
Antigonish	Brook	4	2	0
	Brook	5	2	0
	Salmon	1	1	0
Margaree	Brook	4	2	0
	Brook(wild)	–	1	0
	Salmon	Sac-fry	1	0
Miramichi	Brook	5	6	6
	Salmon	Sac-fry	1	0
Charlo	Brook	4	4	4
	Salmon	Sac-fry	1	0
Florenceville	Brook	4	3	3
	Brook (wild)	–	1	1
Cobequid	Brook	4	4	4
	Salmon	2	1	1
Fredericton	Salmon	4	5	0

[a]Defined as the development of CPE in at least one of six replicate tubes.
[b]*Salmo trutta.*
[c]*Salmo gairdneri.*
[d]*Salvelinus fontinalis.*
[e]*Salmo salar.*

and Cardigan does not prove its absence from these stations. It does indicate, however, where a start may be made in the selection of IPN-free trout for brood stock and the early stage propagation of their progeny in accordance with the scheme outlined by Wolf and Quimby (1967) and Wolf et al. (1968) for the control of IPN.

Despite references to the susceptibility of Atlantic salmon to this disease (Snieszko and Wolf, 1958; Parisot et al., 1965; Yasutake et al., 1965) there is no report of the actual isolation of IPN virus from this fish. In our survey, Atlantic salmon obtained from Kedjimkujik and Cobequid were found to be infected and thus an essential criterion in establishing the susceptibility of this species was satisfied. The relatively low incidence may be attributed to

the fact that in the salmon specimens examined the disease had not been contracted or that the concentration of virus was too low in many specimens to be detected in our system. Further work with IPN in relation to newly hatched and juvenile Atlantic salmon is planned.

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Sexual Dimorphism in the Cyclopterid Fish *Eumicrotremus orbis*

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Eumicrotremus orbis exhibits marked sexual differences in the size and number of the taxonomically important dermal tubercles and in coloration. The tubercles in females are larger and more numerous than those in the males. Mature females are pale green whereas males are dull orange to reddish-brown. Eggs taken from ripe females collected during January and February 1967 averaged 2.0 mm in diameter. Each female carried an average of 202 eggs. The presence of recently hatched juveniles suggests that *E. orbis* spawns in February.

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THE PACIFIC SPINY LUMPSUCKER, *Eumicrotremus orbis* (Günther), is widely distributed throughout the North Pacific Ocean, ranging from the eastern coast of Sakhalin and the southern Kuril Islands in the west, across the Bering Sea, and south along the eastern Pacific to the Puget Sound area. It is characterized, among other things, by the presence of a ventral adhesive disc modified from the pelvic fins and by a distinctive pattern of dermal tubercles on the head and body. The size and distribution of these tubercles were used extensively by Ueno (1954) and Lindberg and Legeza (1955) in distinguishing the species of this genus.

During the course of a study on the functional morphology of the adhesive disc of the spiny lumpsucker, marked sexual differences in coloration and in the size and number of the taxonomically important tubercles were noted. Although sexual differences in disc size have been previously reported for other species of this family (e.g., Borckert, 1889, on *Cyclopterus lumpus*; and Kobayashi, 1962, on *Aptocyclus ventricosus*), there are no reports of sexual dimorphism in *E. orbis*.

The description of the dimorphism in the tubercles is based on specimens from the eastern Pacific ranging from Puget Sound, Washington, to Kodiak Island, Alaska. These specimens are from the research collection of the Institute of Fisheries, University of British Columbia. Alizarin Red in 4% KOH was used to stain the specimens for the examination of the tubercles. Gonads of all specimens were examined to confirm the sexes. The coloration was described from live specimens seined at the beach adjacent to the Lumberman's Arch swimming pool in Stanley Park, Burrard Inlet, Vancouver, B.C., during the months from September through April 1965–67. Offshore from the sandy beach, the bottom is made up of coarse sand and small rocks, and the vegetation in the area consists mainly of eelgrass (*Zostera marina*) and kelp (*Nereocystis luetkeana*).

Sexually mature adult specimens of *E. orbis* were caught abundantly from October to March with the peak abundance occurring in November. These specimens displayed distinct sexual differences in coloration and tubercle size and number. The females were pale green and the males were dull orange to reddish brown. The green coloration in the females was most pronounced inside the mouth, on the throat, around the anal opening, and along the bases of the pectoral, anal, and caudal fins. The tips of the large tubercles on the ventral half of the body were also pale green and the areas around these tubercles were yellow. The adhesive disc was bright green and the head and dorsum were dark brown to black. In the males the reddish-brown coloration was darker on the head and dorsum and lighter on the belly; numerous small, light blue, almost irridescent spots were scattered over the head, dorsum, and first dorsal fin. The large tubercles around the anus were white with dark rings surrounding the bases, and the naked area surrounding the anal opening was orange. The parts of the pectoral fins surrounding the adhesive disc were bright orange whereas the disc itself was yellow with only a few very small orange spots on the edges. Similar orange spots were also scattered on the second dorsal, anal, and caudal fins.

The large primary tubercles covering the head and body of the spiny lumpsucker are arranged in distinct rows. The patterns of these rows are similar

in both sexes and conform to those described and illustrated by Lindberg and Legeza (1955) for *E. orbis*. However, the sizes and numbers of the tubercles making up the rows vary markedly between the sexes. The females are distinctly better armored. The primary tubercles in these (Fig. 1A) are very large in comparison with those in the males with adjacent tubercles nearly touching one another. In addition, a few small secondary tubercles are interspersed in the areas between the primary ones, giving the appearance of an almost complete armor covering the head and body. In the males (Fig. 1B), the primary tubercles are much smaller, resulting in the presence of large naked areas between the tubercles; only a very few secondary tubercles, if any, occur within these naked areas. In the females, the primary tubercles, although decreasing in size posteriorly, extend nearly to the end of the caudal peduncle,

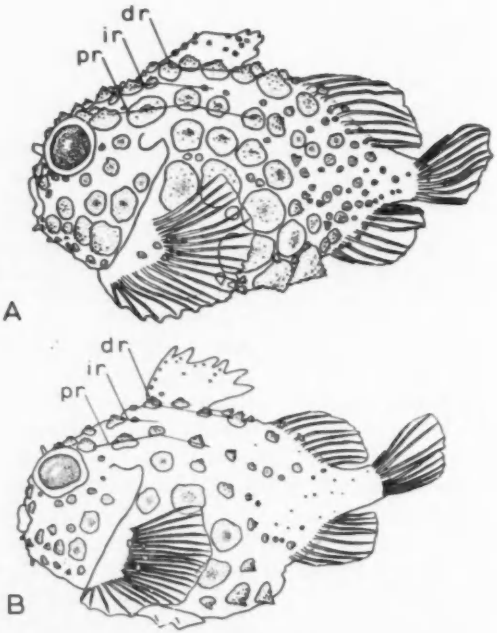

FIG. 1. Dermal tubercles in *Eumicrotremus orbis*. A, female, 36 mm SL; B, male, 31 mm SL. *dr* = dorsal row of tubercles; *ir* = interorbital row; *pr* = postorbital row.

whereas in the males, the tubercles do not extend as far as the peduncle but are replaced in this region by fleshy papillae. A difference in the posterior extent of the interorbital row (cf. Lindberg and Legeza, 1955, fig. 2) is also apparent between the sexes. In the females, the tubercles of this row continue posteriorly beyond the origin of the first dorsal fin as minute tubercles passing between the dorsal and postorbital rows. However, in the males, the tubercles of the interorbital row end abruptly at the level of the origin of the first dorsal fin, leaving a naked space between the dorsal and postorbital rows.

The arrangement of the tubercles as described above is consistent in the females examined; the males, however, are variable with some specimens nearly approaching the female condition whereas others have almost no tubercles posteriorly beyond the position of the origins of the second dorsal and anal fins. Immature males of less than 20 mm standard length (SL) tend to be less differentiated from the females than are the older males; however, the differences in these smaller males are still detectable.

The eggs from 17 obviously ripe female specimens, which were taken during January and February 1967, were collected and examined. The average size of the large orange eggs was 2.0 mm in diameter and the number averaged 202 eggs per female (range 169–229). The females were between 34 and 39 mm SL. Subsequent dissection of the specimens revealed a large number of residual eggs about half the size of the stripped eggs, as well as numerous other eggs of progressively smaller size. Perhaps *E. orbis* spawns more than once during a single spawning season.

Juveniles about 5 mm SL were caught in abundance during early April 1966. The actual spawning act and the nesting sites were not observed. However, if we assume that eggs of *E. orbis* develop in 5–6 weeks as they do in the well-known Atlantic species *Cyclopterus lumpus* (McIntosh, 1886; Gill, 1907), the occurrence of its young in early April suggests that the Pacific spiny lumpsucker spawns during February.

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Activity Periods of Some Fishes in Heming Lake, Canada

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On the basis of the numbers of fish caught per unit of time in Heming Lake during a spring–summer period, the white sucker (*Catostomus commersoni*) was most active during daylight. The following species were most active during darkness: northern pike (*Esox lucius*), whitefish (*Coregonus clupeaformis*), and walleye (*Stizostedion vitreum vitreum*).

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THE ACTIVITY PERIODS of freshwater fish have been studied for many years. Most workers have studied activity by setting gillnets and observing and recording changes in catch per effort at selected times during the day and night. The information reported herein was collected at Heming Lake, Manitoba, during an investigation of the relationship of pike and coregonine fishes, as part of a general study of the life history of the pseudophyllidean cestode *Triaenophorus crassus*. Activity is defined here as the movement of fish either horizontally or vertically. The methods used to collect the data were not highly sophisticated and the results are presented here merely to add to the scanty knowledge of the subject, as they were obtained at a latitude of 54°N, a considerably higher latitude than any hitherto reported.

The ability of fish to detect or avoid a net, or both, may vary between species and categorical statements on activity based on gillnet catches and should be avoided because of this possible bias.

In this report the index of fish activity was based on the number of fish caught in a specific unit of time in gillnets set at two selected stations. The assumption was made that the more active a fish became the greater the chance that it would be caught. The fish population was sampled with gillnets, 46 m long, of 3.8, 6.9, and 8.9 cm stretched mesh. One gang of these nets was set in a shallow area (approximately 3 m) and another was set in deeper water (5–6 m), and each was lifted about every 4 hr during a 24-hr period. These experimental sets were made 11 times between May 17 and August 22. It was impossible to run the sets precisely on the hour because of occasional inclement weather, time lost locating marker buoys at night, and time required to examine fish. The catch of fish per net-hour was derived on the basis of the number of fish taken per hour during each 4-hr period throughout the investigation, e.g., the numbers of fish captured between the hours of 2400 and 0400 were averaged and the catch per net-hour was plotted at 0200 hr.

The catch of northern pike, *Esox lucius*, in shallow water was highest during the hours of darkness (Fig. 1). After sunrise the catch per unit of effort declined sharply and then slowly increased until a peak was reached soon after sunset.

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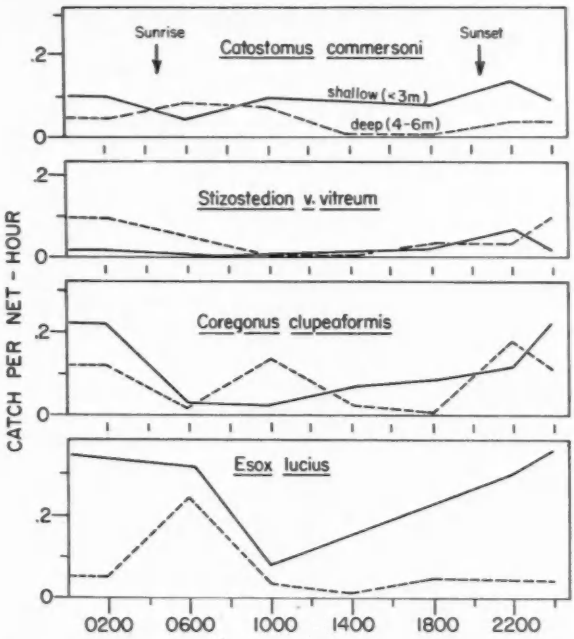

FIG. 1. Catches per net-hour of four species of Heming Lake fish from shallow and deep water during the period May 17 to August 22. Sunrise ranged from 4:52 to 5:35 and sunset from 20:36 to 20:04 CST.

In deeper water the catch rose sharply just after sunrise, declined until late afternoon, and then increased slightly with approaching darkness.

The catch per unit of effort of whitefish, *Coregonus clupeaformis*, in shallow water was highest during the hours of darkness (Fig. 1). In the deeper water the catch was high during the hours of darkness and again in midmorning. When mayflies emerged (mid-July), an increase in catch per unit of effort was noted in all samples during the 24-hr study period.

The data obtained from walleye (*Stizostedion vitreum vitreum*) catches were sparse but suggested nocturnal movement (Fig. 1). Catch per unit of effort in both shallow and deep areas was higher during the hours of darkness than during the day.

In shallow water the white sucker, *Catostomus commersoni*, was captured in highest numbers between sunset and sunrise (Fig. 1). The catch declined in the early morning and then increased irregularly until evening. In deep water the catches were highest between sunrise and 1200 hr and then declined.

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Transferrin Variants in Pacific Hake (*Merluccius productus*)

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Four transferrin bands were detected by starch-gel electrophoresis in serum and vitreous fluids of Pacific hake from Puget Sound, Washington, and off the mouth of the Columbia River. The patterns of the variants and their frequencies in samples from the two areas indicated that each band reflects one allele at a single locus. Frequencies of the alleles differed significantly between areas.

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TRANSFERRIN VARIANTS have been reported in several families of teleost fishes including clupeids (Møller and Naevdal, 1967), cyprinids (Creyssel et al., 1966), catostomids (Koehn and Johnson, 1967), gadids (Møller, 1966; Møller and Naevdal, 1967; Jamieson, 1967), scombrids (Barrett and Tsuyuki, 1967; Fujino and Kang, 1968), and pleuronectids (de Ligny, 1967). This report describes transferrin variants found in the serum of Pacific hake (*Merluccius productus*) from Puget Sound, Washington, and off the mouth of the Columbia River. It is part of a series of studies on genetic differences between these two groups of Pacific hake to determine if they are reproductively isolated from each other.

Blood samples were collected from live fish by cardiac puncture or severing the tail. Blood was centrifuged after clotting; the serum was pipetted into glass vials and stored at −30 C. Starch-gel electrophoresis was carried out as described by Kristjansson (1963), and a buffer system described by Ridgway et al. (1969) was used. The variable proteins described here were identified as transferrins from samples of serum by autoradiography as described by Giblett et al., (1959). The transferrin patterns exhibited no detectable qualitative differences between freshly collected sera and those stored up to 2 years, although prolonged storage caused some loss in staining intensity.

Transferrins in vitreous fluids were studied with 30 fish from which both serum and vitreous fluids had been collected. The vitreous transferrins required fivefold concentration by dialysis of the vitreous fluids before they could be detected on starch gels and were highly labile, being undetectable from eyes that had been frozen for more than 1 month. Parallel transferrin phenotypes between the vitreous and serum were found for each of the 30 fish. The finding that vitreous fluids of freshly caught Pacific hake can be used to detect transferrins is of value. These fluids can be obtained in the laboratory from frozen fish, whereas live fish are required for obtaining blood sera.

Four transferrin bands having different electrophoretic mobilities were detected (Fig. 1) in the serum. Only two fish had the D band; both were AD

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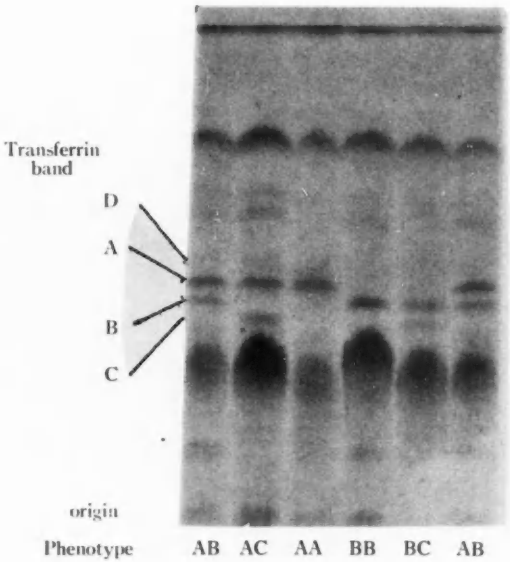

FIG. 1. Bands in starch gel illustrating transferrin phenotypes from serum of Pacific hake. Position of the D band is indicated although no D phenotypes are seen in this figure.

TABLE 1. Frequencies of transferrin phenotypes and A and B alleles in serum of Pacific hake from Puget Sound and the Pacific Ocean.

Date of sampling	Phenotype[a]					Allele frequency		No. of fish	df	X^2 [c]	*P*
	AA	AB	BB	AX[b]	BX[b]	A	B				
Puget Sound (near Everett, Wash.)											
Jan. 1967	18	14	1	1	0	0.750	0.235	34	1	1.02	0.40
	(19.1)	(12.0)	(1.9)	(0.8)	(0)						
Feb. 1967	14	11	4	3	0	0.672	0.297	32	1	0.12	0.70
	(14.5)	(12.0)	(2.5)	(1.9)	(0)						
June 1968	25	17	7	0	0	0.684	0.316	49	1	1.93	0.15
	(22.9)	(21.2)	(4.9)	(0)	(0)						
Total	57	42	12	4	0	0.696	0.287	115	1	0.37	0.60
Sum of chi-square									3	3.44	0.40
Heterogeneity									2	3.04	0.25
Pacific Ocean (near mouth of the Columbia R.)											
May 1967	22	36	11	8	5	0.536	0.384	82	1	0.67	0.45
	(23.8)	(33.8)	(12.1)	(7.0)	(5.0)						
July 1967	37	62	13	5	4	0.583	0.380	121	1	2.28	0.12
	(41.1)	(53.6)	(17.4)	(5.2)	(3.6)						
Total	59	98	24	13	9	0.564	0.382	203	1	2.55	0.10
Sum of chi-square									2	5.50	0.07
Heterogeneity									1	2.95	0.07

[a]Observed and (in parentheses) expected frequencies. Expected frequencies based on the assumption that distribution of phenotypes fits the expansion of allelic frequencies $(A + B + X)^2 = 1$ (Hardy-Weinberg equilibrium).
[b]X — Combined C and D phenotypes.
[c]B, C, and D alleles were pooled in chi-square computation.

phenotypes and were caught off the mouth of the Columbia River. Presumably each transferrin band reflects a different allele at the same locus; these alleles were designated Tf^a, Tf^b, Tf^c, and Tf^d, respectively. The present data as well as the verification of transferrin allelism in other vertebrates where family data were available (Ashton, 1958; Braend and Stormont, 1964; Giblett, 1962) support this assumption.

The distribution of transferrin phenotypes in Pacific hake from Puget Sound and the ocean off the mouth of the Columbia River did not deviate significantly from expected numbers, assuming Hardy-Weinberg (Stern, 1943) frequencies either for individual samples or for combined phenotypes in each area (Table 1). The difference between the average Tf^a allelic frequency of the Puget Sound population and ocean population was significant ($t = 3.57, 0.05 > P > 0.01$). Highly significant differences have been found between Puget Sound and ocean fish for three other polymorphic systems: esterase, lactate dehydrogenase, and muscle protein (Utter, MS, 1969a, MS, 1969b). The allelic distribution of these four systems and the different growth characteristics and seasonal distribution of the fish (Nelson, 1967) provide good evidence of the reproductive isolation of the two populations.

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Quality Evaluations of Freeze-Dried Cod Steaks

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WOOD, A. L., AND R. LEGENDRE. 1969. Quality evaluations of freeze-dried cod steaks. J. Fish. Res. Bd. Canada 26: 3271–3274.

Taste panel comparisons between freeze-dried and frozen Atlantic cod steaks, processed at two sites, were made to observe the effects of various experimental conditions on the quality of the freeze-dried product. No significant difference in quality was attributable to processing site, sex of fish, freezing rate, or thickness of samples. Freeze-dried steaks from prerigor fish were superior in flavour, texture, and general quality to those from postrigor fish. Freeze-dried steaks were invariably distinguishable by their tougher texture from similar frozen steaks, although appearance and flavour were not significantly different.

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THE PURPOSE OF THIS INVESTIGATION was to evaluate and make observations on factors affecting the quality of freeze-dried cod steaks. The work was carried on at Halifax and Grande Rivière simultaneously to permit comparisons between two processing sites, each using a different type of dryer. Freeze-dried steaks were compared with frozen steaks concerning sex, state of rigor, rate

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of freezing, sample thickness, and sample temperature and pressure during drying. Taste panel evaluations were made for flavour, texture, and general quality.

Experimental procedures — Seventy-two cod fish, 60–75 cm long and 1.5–3.0 kg in weight, were taken alive from inshore Atlantic waters between March and October and held alive in tanks of sea water at 2–3 C for at least 3 days before killing, heading, and gutting. Eighteen of these fish were quick-frozen immediately, prerigor. Eighteen were slow-frozen and are referred to as being prerigor though they may have entered rigor before or during the freezing. The remaining 36 fish were iced for not more than 5 days, until they were out of rigor. Half of these were then quick-frozen, the other half slow-frozen. Quick-freezing reduced the temperature at the center of the fish to −25 C in about 3½ hr, whereas slow-freezing took about 18 hr to reach the same temperature. Nine fish of each of these four lots were shipped frozen in polyethylene bags to Grande Rivière and the remainder to Halifax for processing.

The frozen fish were sawn into steaks, which were repacked in polyethylene bags and stored at −25 C until admitted to the dryer, or held as frozen controls for comparison with the freeze-dried samples. Each fish yielded an average of 12 steaks.

In the Halifax freeze-dryer, the steaks were supported by a balance having a gross product load of 2000 ± 0.2 g, between two electrically heated plates. The internal condenser had a −40 C blank-off temperature. Instrumentation included a recording temperature controller, absolute pressure recorder, and copper-constantan probes for recording sample temperatures.

The dryer at Grande Rivière was modified to permit the control of radiant heaters by thermocouples fixed to the sample surface. Weight loss of the samples was observed on a balance similar to the Halifax installation. Condenser temperature to −54 C was possible, which, in conjunction with an oil diffusion pump, permitted pressures to 0.001 mm mercury within the drying chambers.

The equipment and procedures used for freeze-drying have been described in more detail by Legendre and Wood (1966).

Normal drying conditions at Halifax were 40 C maximum sample temperature and 0.06 mm mercury minimum dryer pressure, and those at Grande Rivière were 30 C and 0.03 mm. Maximum sample temperature was that of the steaks at the end of the drying period and was the highest temperature attained by the fish previous to baking.

Frozen steaks were placed in the drying chamber and pressure reduced before melting occurred. Heat was applied only after the dryer pressure became constant, by which time the sample temperature was fairly stable at or about −30 C. Drying was discontinued when the weight loss reached 0.1% per hour.

The freeze-dried steaks were packaged in polyethylene bags until required, then reconstituted in distilled water at room temperature, and baked at 260 C for about 5 min for each 7 mm thickness. Frozen controls were baked 50% longer. No seasoning or other additions were used.

Eight experienced taste panelists were served baked freeze-dried and unidentified baked frozen samples and made a total of 24 judgments for flavour, texture, and general quality on a scale from 0 to 100 (Dyer et al., 1964). Students *t*-distribution was used to estimate a true mean rating for each sample (Snedecor, 1956), and to compare means for two different samples (Volk, 1958). The confidence level selected was 0.05.

Results — There was no significant difference in appearance between frozen and freeze-dried cod steaks if the latter were not permitted to exceed 60 C, during drying, for more than 1 or 2 hr. Prolonged exposure to 60 C caused only a slightly yellowish discolouration, but one hour at 120 C was sufficient to scorch these samples markedly.

For steaks dried at 30–40 C maximum sample temperature and 0.03–0.06 mm mercury minimum pressure, no significant difference in taste panel ratings was found attributable to variations in processing site, sex of fish,

freezing rate, or thickness of samples while state of rigor was constant (Table 1). Steaks from prerigor fish, however, were superior in flavour, texture, and general quality to those from postrigor fish.

TABLE 1. Comparisons of mean scores from 24 taste panel evaluations each for flavour, texture, and general quality of single cod steaks freeze-dried at two sites, at 0.03–0.06 mm mercury minimum dryer pressure and 30–40 C maximum sample temperature, under various experimental pre-drying conditions.[a]

Pre-drying conditions	Fish sample[b]	Flavour	Texture	General quality
Postrigor				
Similar fish	12 G	48	34	42
	15 G	50	26	36
Site: Halifax	16 H	48	46	37
Grande Rivière	17 G	46	43	36
Sex: male	15 G	50	26	36
female	17 G	46	33	36
Freezing rate: slow	13 H	45	53	39
quick	14 H	41	49	39
Thickness (*mm*): 8	9 G	45	35	44
16	12 G	48	34	42
Prerigor				
Sex: male	6 H	67	51	55
female	5 H	71	38	51
Freezing rate: slow	1 H	72	69	67
quick	3 H	68	63	60
Thickness (*mm*): 8	3 H	68	63	60
16	6 H	67	51	55
Quick-frozen				
Prerigor	3 H	68*[a]	63	60*
Postrigor	14 H	41*	49	39*
Slow-frozen				
Prerigor	1 H	72*	69*	67*
Postrigor	13 H	45*	53*	39*
Prerigor	2 G	60	69*	62*
Postrigor	12 G	48	34*	42*

[a]* = significantly different at $P = 0.05$.
[b]G, Grande Rivière; H, Halifax.

For steaks dried at two different temperatures and three pressures, the higher temperature degraded flavour in quick-frozen prerigor and in slow-frozen postrigor steaks, and also texture and general quality in slow frozen postrigor fish (Table 2). Steaks dried at 0.03 mm minimum dryer pressure were of the best quality. A significantly lower texture and general quality rating resulted when the pressure was reduced to 0.001 mm. At 2.0 mm, no significant difference was observed.

Ratings on freeze-dried steaks were generally lower than on similar frozen fish, which were rated between 55 and 83 for general quality. The best quality

TABLE 2. Comparisons of mean scores from 24 taste panel evaluations each for flavour, texture, and general quality of single cod steaks from similar fish freeze-dried at two sites, at different maximum sample temperatures and minimum dryer pressures.[a]

	Fish sample[b]	Flavour	Texture	General quality
Comparison of sample temp (C)				
Prerigor, quick-frozen 40	5 H	71*[a]	38	51
80	8 H	54*	44	49
Postrigor, slow-frozen 30	12 G	48*	34*	42*
70	19 G	33*	14*	25*
Comparison of dryer pressures (mm)				
Prerigor, slow-frozen 0.001	7 G	48	41*	47*
0.03	2 G	60	69*	62*
2.0	4 G	62	53	57

[a]* = significantly different at $P = 0.05$.
[b]G, Grand Rivière; H, Halifax.

freeze-dried steaks produced (sample 1 H, prerigor, slow-frozen) when compared with the best quality similar frozen fish was rated by the panel as significantly tougher in texture and lower in general quality.

Discussion — Appearance and flavour of freeze-dried cod steaks were not significantly different from comparable frozen fish, but the taste panelists were invariably able to identify the freeze-dried by their tougher texture. Prerigor fish dried at 30–40 C and 0.03–0.06 mm mercury pressure produced acceptable cod steaks, in spite of this textural difference. Since most fish landed commercially along the Atlantic coast is postrigor and quick-frozen, it is unlikely that freeze-dried cod steaks could be rated as highly as the best quality frozen product at the time of processing.

Unfortunately, not all frozen fish is of prime quality when it reaches the consumer because of prolonged storage, irregular holding temperatures, and poor distribution methods. Comparisons on the basis of consumer acceptance at the time of consumption could favour the freeze-dried product. For use in chowder, fish cakes or flakes, the tougher texture would be desirable, and where refrigeration is not available, freeze-dried cod steaks are the nearest to fresh fish quality obtainable by any known process.

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Night Feeding of Brown and Rainbow Trout in an Experimental Stream Channel

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JENKINS, THOMAS M., JR. 1969. Night feeding of brown and rainbow trout in an experimental stream channel. J. Fish. Res. Bd. Canada 26: 3275–3278.

This study sought to determine if stream-living brown and rainbow trout (*Salmo trutta* and *Salmo gairdneri*) will feed on drifting terrestrial insects at night. Groups of fish were confined in segments of a rocky-substrate mountain stream, and marked ants were introduced to the current from observation towers equipped with feeding tubes. After the last introductions of an experiment, the fish were removed and their stomachs were examined for marked ants.

Although fish of both species fed at night, they appeared to take a smaller percentage of the ants provided than did day-feeding groups studied for comparison. Fish feeding under bright moonlight and starlight captured introduced ants at about the same rates. The results suggest that trout in the type of stream studied feed or are in feeding readiness at nearly all hours of the day or night, at least in the summer months.

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LITTLE IS KNOWN of night feeding by stream-living trout, despite its obvious ecological significance. Some salmonids evidently rest on or hide in the substrate at night (juvenile *Salmo salar*, Elson (1942) and Kalleberg (1958); juvenile *Oncorhynchus tshawytscha* and *Salmo gairdneri*, Edmundson et al. (1968)), whereas others appear to feed on organic drift during at least the early hours of the night (*Salmo trutta*, Elliott (1967); juvenile *Oncorhynchus kisutch*, Mason (1969)). This note reports the results of experiments in which brown and rainbow trout (*S. trutta* and *S. gairdneri*) fed on small drifting insects throughout the darkest of clear nights, in a small observation stream with regulated flow but natural topographical details and food supply.

The apparatus for this study consisted of two adjoining segments of stream in which experimental groups of fish could be confined. Each segment was overlooked by an observation tower provided with a tube for introducing food at a known point (Fig. 1).

Brown trout were studied in the upstream segment and rainbow trout in the downstream segment. The brown trout were 1- to 3-year-old wild fish taken by fly angling from Convict Creek in eastern California, the source of water for the experimental channel. The rainbow trout for experiments 1–4 were hatchery fish that had overwintered in Convict Creek; those for experiment 5 were underyearlings taken directly from Hot Creek state fish hatchery. One randomly selected group of five fish was allowed to settle in each of the stream segments for 3–6 days prior to experimental feedings, because the initial schooling and intense aggression occurring in such groups for the first day or two after introduction disrupt feeding on naturally occurring food (Jenkins, in press).

Ants were chosen as prey because: (*a*) several species are common in stomachs of naturally feeding fish of both species taken day or night from the study stream; (*b*) they nearly always

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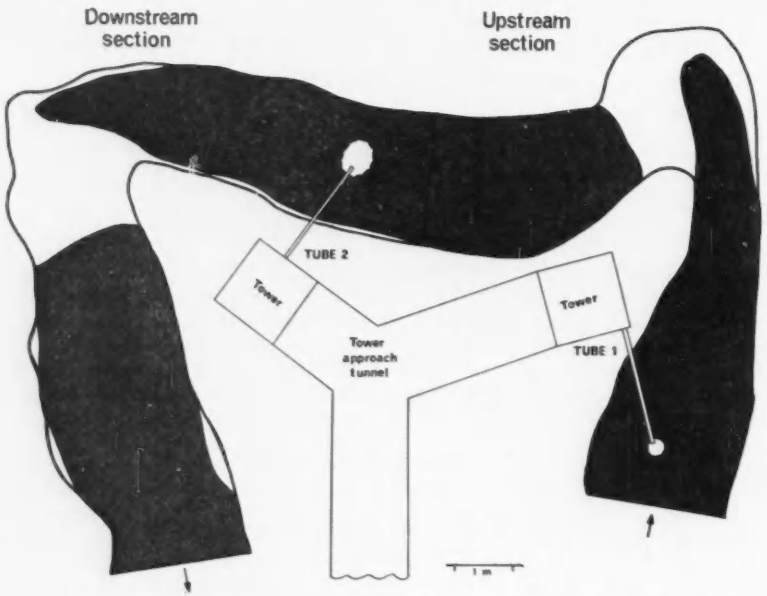

FIG. 1. Plan of experimental apparatus. Three fish barriers divided the 24-m stretch into a 10-m upstream segment and a 14-m downstream segment. The two towers were enclosed except for windows about 3-m from the water surface, and were provided with enclosed tunnels for entering without disturbing fish in the stream. The tube (2.5-cm diam metal conduit) in the upstream section (tube 1) ended about 40 cm above the water, and that in the downstream section (tube 2) about 50 cm above. Shading denotes areas of surface turbulence. Broken circles at the end of tubes enclose the areas in which ants landed on the water. The upstream segment was used for brown trout, and the downstream segment for rainbow trout.

float on the water surface; (*c*) they were available in the large numbers necessary; (*d*) they can be marked with little mortality; and (*e*) they do not cling or adhere to the feeding tubes. The species chosen had an orange head and thorax and a black abdomen, and was rather large (4–8 mm). Individuals were marked with a small spot of model airplane dope on the dorsal surface of the thorax or abdomen, giving two distinct marks for each color. Two colors were used in the experiments on June 10–11, June 16, and June 25–26 (4 separate marks); seven were used in the experiment on June 20–21 (14 marks); and 8 in the experiment on September 30 (16 marks).

Ants were introduced in series of 20 or 30 from each tube, with the rainbow trout in the downstream segment always being fed first. In each series, abdomen marks were introduced to the upstream segment (tube 1), and thorax marks of the same color were introduced to the downstream segment (tube 2). A different color was used for each series. At the rate of about one ant dropped every 10 sec, the introductions of 40 or 60 ants took 10 min or less. At night the tower windows were completely covered during feeding, and a dim red light was used for manipulation of ants. Observations indicated that ants introduced but not captured moved downstream out of reach within less than 5 min after they entered the current.

About 15 min after the last ant of an experiment was introduced, the fish were removed by electrofishing and the numbers of marked ants in their stomachs and intestines were recorded.

Results and discussion — Results of the five experiments (Table 1) clearly demonstrated feeding on ants at night by groups of both species. Comparison

TABLE 1. Design and results of the five feeding experiments during summer, 1968. Experiments 1, 2, and 4 each involved two 10-min series of introductions spaced 4 hr apart (see text), experiment 3 seven series spaced 1 hr apart, and experiment 5 eight series ½ hr apart; five fish were used in each experiment. Since tube 1 ants passed by the brown trout first, the number escaping into the downstream segment is unknown. The percentages of tube 1 ants captured by the rainbow trout (column 6) are based on the original numbers introduced, so the actual percents of available ants captured may have been considerably higher. Twilight was considered ended when no glow from sunlight remained in the west.

Date	Times feeding series began (Pacific Standard)	Illumination type	No. ants from each tube	Ants captured (%)			No. fish that captured marked ants	
				Brown	Rainbow			
				Tube 1	Tube 1	Tube 2	Brown	Rainbow
June 10–11	2200	Full moon	30	0	7	0	0	3
	0200		30	30	13	13	1	2
June 16	1200	Sunlight	30	37	37	57	2	4
	1600		30	67	10	93	2	3
June 20–21	2100	Starlight	20	0	10	15	0	2
	2200		20	0	5	0	0	1
	2300		20	0	5	0	0	1
	0000		20	5	20	5	1	3
	0100		20	0	5	0	0	1
	0200		20	5	10	10	2	1
	0300	Last-quarter moon	20	0	40	5	0	3
June 25–26	2200	Starlight	30	7	0	10	1	2
	0200		30	0	10	7	0	2
Sept. 30	1630	Twilight	20	35	10	10	2	3
	1700		20	35	10	5	2	3
	1730		20	45	25	5	2	4
	1800		20	85	0	5	2	1
	1830	First-quarter moon	20	20	0	0	2	0
	1900		20	5	0	0	1	0
	1930		20	20	0	0	1	0
	2000		20	15	0	0	1	0

of day and night results suggested that groups of trout accustomed to the food supply of the study stream (i.e., all of the brown trout, and rainbow trout of experiments 1–4) took a smaller percentage of the terrestrial insects available at night than they did in the daytime. There was no indication that bright moonlight as a light source led to a greater rate of food capture than starlight alone.

Since drift sampling (Jenkins, unpublished data) showed nighttime abundance of terrestrial food (primarily ants and beetles) in the experimental stream to be about the same as or lower than daytime abundance, the benefit gained from each hour feeding on terrestrials would be proportionally less at night than in daylight. However, there is a marked increase in the number of immature aquatic insects drifting at night, which would more than compensate for a decrease in capture rate (provided that feeding on subsurface drift is subject to the same limitations as feeding on surface drift).

Acknowledgments— I am grateful to the California Department of Fish and Game for providing many of the fish studied.

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Synonymy of the Polychaete *Scoloplos acutus* with *S. armiger*

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CURTIS, MARK A. 1969. Synonymy of the polychaete *Scoloplos acutus* with *S. armiger*. J. Fish. Res. Bd. Canada 26: 3279–3282.

Some species of *Scoloplos*, including *S. acutus*, have been described as differing from *Scoloplos armiger* by the absence of distinctive hooks (crotchets) in the thoracic neuropodia and by the absence of subpodial papillae in the region adjacent to the junction of thoracic and abdominal setigers. Although these species have previously been synonymized with *S. armiger*, little objective evidence has been put forth to support the synonymies and the species persist in the literature. Data presented here demonstrate that the presence of hooks and subpodial papillae is related to growth and so their absence cannot be considered a good criterion for the discrimination of separate species.

Received June 23, 1969

THE ORBINIID POLYCHAETE, *Scoloplos armiger*, has been known to science since its description by O. F. Müller in 1776 as *Lumbricus armiger*. In 1828 Blainville established the genus *Scoloplos*, with *S. armiger* as the type species. McIntosh (1910) presents an extensive list of synonyms to 1909, and Hartman (1957) and Pettibone (1963) cite more recent observations.

Scoloplos acutus was first distinguished by Verrill in 1873 as *Anthostoma acutum* and later, in 1881, was amended to *S. acutus* by the same author. It has been synonymized with *S. armiger* by Webster and Benedict (1887), Fauvel (1927), and Hartman (1944). Although Hartman has considered the two species synonymous, she describes *Haploscoloplos alaskensis* (1948), which again differs from *S. armiger* by the absence of hooks. Pettibone (1954) synonymized *H. alaskensis* with *S. armiger*, while noting that some small *S. armiger* occurred in Alaska without hooks. However, Pettibone (1963) has maintained *S. acutus* separate from *S. armiger* on the basis of the same characteristic that was considered inadequate for the separation of *H. alaskensis*.

In benthic samples collected at Tânquary Fiord, Ellesmere Island (81°N, 80°W) specimens of the genus *Scoloplos* were encountered that did not always exhibit the characteristics of either *S. armiger* or *S. acutus*. The specimens were obtained from six 0.07 m² grab samples taken at a depth of 10 m. Since the animals were always broken posteriorly, width was selected as an indication of relative size. The width of each specimen was measured at the junction of abdominal and thoracic setigers and the specimen was placed in the nearest of several size categories. The number of thoracic setigers was counted in each instance, and the setiger upon which branchiae first appeared was noted. Numbers of thoracic and abdominal papillae were noted whenever these structures occurred. Hooks present in the first, third, and fifth neuropodia were counted and additional neuropodia were frequently examined.

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The pattern arising from this information indicates that *S. acutus* is the juvenile of *S. armiger*. Table 1 shows hooks and papillae to be characteristic of larger individuals whereas the smallest do not possess them. An intermediate stage is shown in which the hooks are present, but the papillae are lacking. Specimens with papillae and without hooks were not found in the six grab samples, but this combination of characters was exhibited by two specimens from other collections in the fiord. It would then appear likely that hooks generally form before papillae develop.

TABLE 1. The presence of papillae and hooks in *Scoloplos armiger* as related to size. The number of specimens in each category is listed beside the percentage of specimens in each size group.

Width of specimen (*mm*)	Without papillae or hooks	Without papillae, hooks present	With papillae and hooks	Totals
0.5	6 (100%)			6
0.75	4 (36%)	4 (36%)	3 (28%)	11
1	3 (18%)	2 (12%)	12 (70%)	17
1.5	1 (8%)		11 (92%)	12
2			4 (100%)	4
Totals	14	6	30	50

Details of developmental changes associated with the early growth of *S. armiger* have been elucidated by Anderson (1959). He describes an early stage consisting of three thoracic setigers followed by six intermediate setigers and then by abdominal setigers that possess branchiae. As setigers are forming at the posterior end of the worm, additional thoracic setigers result from the transformation of intermediate and early abdominal setigers.

According to the data presented in Table 2, an increase in the number of thoracic setigers is directly related to growth. This gradual increase in thoracic setigers accounts for the presence of reduced branchiae on the first segments that bear them. The development of the branchiae ceases when the original abdominal setigers are transformed (Anderson, 1959). Among the

TABLE 2. The number of thoracic setigers related to the size of *Scoloplos armiger*. Numbers of individuals occurring in each category are shown.

Width of specimen(*mm*)	No. of thoracic setigers								Totals
	10	11	12	13	14	15	16	17	
0.5	1	2	3						6
0.75				5	5	1			11
1					4	9	3	1	17
1.5						1	5	6	12
2							1	3	4
									50

Tânquary Fiord specimens the branchiae commonly began on setiger 10 (9–14).

Subpodial papillae may likewise form only on abdominal setigers, but there is no direct evidence to suggest this. When present, the papillae usually begin on setiger 14–16, regardless of the size of the animal.

Hooks are located along the anterior ventral border of each neuropodium involved. Their origin is often attributed to breakage and subsequent abrasion of the longer setae, rather than to a unique development of their own (McIntosh, 1910). Although there is no conclusive evidence to the contrary, breakage seems an unlikely explanation for the origin of these structures. The distinctly curved hooks always possess smoothly rounded tips. Broken neurosetae are straight with jagged edges at the broken end. Since intermediate stages between broken setae and well-formed hooks are not found, there is little reason to suppose that they are different forms of the same structure.

In the specimens examined only the anterior thoracic setigers bear hooks. Generally the first five to seven setigers are involved, and the number of hooks in any single neuropodium does not exceed 10. Since *S. armiger* has been known to bear hooks in all thoracic setigers (Pettibone, 1963), considerable variation in this characteristic can be expected.

The genus *Haploscoloplos*, established by Monro in 1933, separates the *Scoloplos* species without hooks from those with hooks. Pettibone (1957) has not accepted *Haploscoloplos* as a valid genus and, in view of the other data presented here, the absence of hooks does not provide an adequate criterion for a generic distinction.

Acknowledgments — The author gratefully acknowledges the guidance of Dr J. W. Wacasey of the Fisheries Research Board, Arctic Biological Station, Montréal, Qué., through discussion of the results and helpful criticism of the manuscript. Field work was carried out during "Operation Tanquary 1967," sponsored by the Defense Research Board of Canada.

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INDEX TO PUBLICATIONS FOR 1969[1]

In 1968 the Fisheries Research Board of Canada published Bulletin 164 containing a list of all articles, in all series, of publications and Studies that appeared up to the end of 1964, together with a subject–author index to all series. From 1965, a subject–author index and list of all Board publications (including Studies, Interpretive Articles, and Miscellaneous Special Publications) have been included in the last issue of each Journal volume. These follow the pattern and style used in Bulletin 164.

The present subject–author index is based on: (*a*) the 12 issues of Volume 26 of the Journal; (*b*) Bulletins 168–172 issued during 1969, and Bulletin 151 which was published in French; (*c*) Circular series and Technical Reports from the Board's establishments issued during 1969 in time to be included; (*d*) "Miscellaneous Special Publications" includes special bindings and pamphlets which do not belong to a particular series of FRB publications; (*e*) Studies No. 1263–1355 (reprints of articles published in other periodicals, bound annually in two parts); (*f*) general reference to the 1968 Annual Report and the 1967/1968 Review; (*g*) Interpretive Articles 117–138 which appeared in non-Board publications, but which are not included in the bound Studies (item *e* above).

Lists of titles of the individual publications and articles immediately follow this index, arranged under the following types of publications. (The list of articles in this Volume 26 of the Journal is in the form of a table of contents of its 12 issues, suitable for binding with this volume.)

Abbreviations used in the index for types of publications:

(The designation "(F)" in the index indicates the article referred to was published in French.)

J — Journal of the Fisheries Research Board of Canada
B — Bulletin of the Fisheries Research Board of Canada
AR — Annual Report of the Fisheries Research Board of Canada
R — Review of the Fisheries Research Board of Canada (biennial)

Circulars of the Fisheries Research Board of Canada:

CHN — Halifax Laboratory, Halifax, N.S.
CJG — Biological Station, St. John's, Nfld.
CNG — Biological Station, Nanaimo, B.C. (General series)
CNS — Biological Station, Nanaimo, B.C. (Statistical series)
CVG — Vancouver Laboratory, Vancouver, B.C.

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[1]Subject index prepared by Neal M. Carter.

J. Fish. Res. Bd. Canada 26: 3283–3379, 1969
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Miscellaneous:

T — Technical Reports of the Fisheries Research Board of Canada
MSP — Miscellaneous Special Publications

Articles by FRB Staff published in non-Board publications:

S — Studies of the Fisheries Research Board of Canada
A — Interpretive Articles of the Fisheries Research Board of Canada

Other abbreviations:

The Provinces and Territories of Canada are abbreviated to:

Alta. (Alberta)	N.W.T. (Northwest Territories)
B.C. (British Columbia)	Ont. (Ontario)
Man. (Manitoba)	P.E.I. (Prince Edward Island)
N.B. (New Brunswick)	Que. (Quebec)
Nfld. (Newfoundland)	Sask. (Saskatchewan)
N.S. (Nova Scotia)	Yuk. (Yukon)

Certain geographical areas (particularly oceans) have their major subdivisions designated by N (north), S (south), E (east), W (west), NE (northeast), etc., also Atl. (Atlantic), Pac. (Pacific).

Certain international commissions are commonly referred to as:
ICNAF (International Commission for the Northwest Atlantic Fisheries)
INPFC (International North Pacific Fisheries Commission)

In the index references, "re" is frequently used to imply "in relation to," "in connection with," and similar meanings; "vs." to imply such meaning as "in contrast to," "as opposed to."

A

Aarts, Margaret Mary
CNS 27 (age composition of 1965 B.C. sockeye, chum, & pink salmon)

Abalone (*Haliotis kamtschatkana*)
B 168 : 29 (no record of toxicity in B.C.)

Able, Kenneth William
J 26(2): 473 (sculpin occurrence and spawning)

Abnormality
J 26(1): 191 (B.C. starry flounders sinistrality)
(11): 3091 (pugheaded landlocked Atl. salmon)

Abramis blicca (*see* Bream, white)

Abundance
J 26(9): 2459 (seasonal, of L. Erie zooplankton)
(10): 2543 (seasonal, of various planktonic copepods, Parry Sound Ont.)
T 108 (rock sole, Hecate Strait, B.C.)

Acanthocephala (spiny-headed worms)
J 26(4): 833 (of yellow perch, Bay of Quinte, Ont.)
(4): 909 (*Pomphorhynchus laevis* in Atl. salmon and use as distribution indicator)
(4): 965 (*Acanthosentis cameroni* n.sp. from an India fish, & key to genus)
(9): 2319 (list of species found in B.C. marine fishes)
T 134 (*Pomphorhynchus laevis* re indicator for Atl. salmon stocks)

Acanthohaustorius millsi (sand-burrowing amphipod)
J 26(2): 361; (5): 1321 (ecology & life cycle, Cape Cod)
(9): 2283 (tolerances & behaviour, Cape Cod)

Acantholiparis caecus (*see* Liparid)
opercularis (*see* Liparid, spinycheek)

Acanthosentis cameroni (an acanthocephalan)
J 26(4): 965 (new species, from an India fish)

Acari
J 26(12): 3101 (of Crecy L., N.B.)

Acarina
J 26(4): 833 (*Hydrachna* larvae on yellow perch gills)

Acartia tonsa (*see* Calanoida)

Acclimation; Adaptation (*see* Salinity, reactions to; Temperature, reactions to)

Acerina cernua (*see* Ruff)

Acetylcholinesterase (*see* Choline; Enzymes)

Achromobacter (*see also* Bacteria)
J 26(10): 2651 (population on vacuum- vs. air-packaged EDTA-treated fish fillets)
(10): 2760 (in culturing algal feed for rearing bivalve larvae)
S 1312 (use of choline or betaine for fatty acid synthesis; also component fatty acids synthesized)

Achtheres (parasitic copepods)
J 26(11): 2987 (re revision of *Salmincola* genus)

Ackman, Robert George
J 26(5): 1385 (lobster disease gaffkemia)
(6): 1577 (herring oils free fatty acids)
(8): 2027 (Nfld. capelin composition)
(8): 2037 (Nfld. capelin lipids)
S 1265 (flame ionization detector)
1266 (LDD & DDD diastereoisomers of phytanic acid)
1286 (occurrence of squalene in fish)
1323 (composition of pristanic acids)
1330 (separation of triglycerides and free fatty acids)
1331 (calculation of equivalent chain length values for fatty acid esters and ketones)
1350 (production of fish protein concentrate from herring)
1351 (load effect in open-tubular GLC)

Acids, amino
J 26(5): 1347 (re culture of calanoid copepods)
(9): 2299 (effect on hemoglobin-catalyzed lipid rancidity)
(10): 2659 (oligochaetes uptake of free, from Toronto harbour sediments)
(11): 2969 (of *Parapenaeus* Atl. shrimps)
T 114 (content of individual, in Canadian Atl. herring meals)
S 1342 (alanine & aspartate aminotransferases in Atl. fishes eggs & sperm)
1347 (composition re proteins secondary structure)
A 125 : 60 (lysine in fish protein concentrates)

Acids, fatty (*see also* Lipids; Oils & fats)
J 26(6): 1577 (origin of free, in Atl. herring commercial oils)
(8): 2030, 2037 (content & composition in Nfld. capelin lipid)

(8): 2237 (inhibitory agents for liberation from trout muscle lipids during cold storage)
(9): 2229 (re rancidity in marine flesh lipids)
(10): 2727 (reaction with Atl. cod muscle protein iced then frozen)
S 1265 (flame ionization detector re gas–liquid chromatography of)
1312 (betaine or choline used by *Achromobacter cholinophagum* for syntheses of; also component fatty acids synthesized)
1323 (diastereoisomeric composition of pristanic acids of marine and terrestrial origin)
1330 (separation from triglycerides by suitable chromatographic procedure)
1331 (esters of multiple branched: chromatographic separation)
1350 (composition of Atl. herring lipids)
1351 (cis & trans isomerism effect in separating monoethylenic fatty acid isomers by GLC)

Acids, nucleic (*see also* Nucleotides)
J 26(3): 543 (DNA re chromosome size difference in polytenic *Pseudocalanus*)

Acrocirridae (Polychaeta Sedentaria)
J 26(10): 2595 (new family, formerly Cirratulidae; new species *Acrocirrus trisectus*; description of other *Acrocirrus* species)

ACTH (*see* Hormones)

Activity; Exercise; Fatigue (*see also* Stress; Swimming)
J 26(1): 63 (coho salmon fry activity & aggression diel cycles)
(1): 93 (temperatures changes effects on acclimated Atl. salmon)
(8): 2165 (brown trout seasonal, re feed availability in a British stream)
(9): 2517 (of Atl. halibut vs. rabbit re temperature, as caused by temperature effect on dehydrogenase enzyme activity)
(12): 3266 (periods of northern pike, whitefish, walleye, & white sucker, Heming L., Man.)
T 116 (*Cylmenella torquata* polychaete in aquarium)

Adams, D.
J 26(8): 2027 (Nfld. capelin composition)
(8): 2037 (Nfld. capelin lipids)

Adams, James Russell
J 26(4): 941 (migration of *Philonema* in salmon)

Addison, Richard Frederick
J 26(6): 1577 (herring oils free fatty acids)
S 1286 (occurrence of squalene in fish)
1330 (separation of triglycerides and free fatty acids)

Adenosine
J 26(3): 704 (in canned Arabian Sea shrimp)
(10): 2621 (phosphate changes in critical freezing zone of Atl. cod muscle)

Adrenaline and derivatives
S 1337 (adrenalectomy effect on American eel plasma cortisol, etc.)

Aeromonas bacteria (*see also* Furunculosis)
J 26(1): 115 (endotoxin effects on coho salmon and rainbow trout metabolism)
(3): 629 (bacteriophages)
(9): 2311 (disinfectants re trout eggs transmission of *Aeromonas liquefaciens*)

Agarum cribrosum (a seaweed)
J 26(10): 2703 (photo)

Age; Age composition (*see also* Size; Length; Longevity; Weight)
J 26(3): 687 (as rainbow trout bottom colour selection factor)
(5): 1289 (W L. Superior longnose suckers)
(8): 2252 (& growth of N.W.T. broad whitefish)
(9): 2339 (& size of shiner perch re embryo number & size)
(9): 2403 (& growth, blackbelly eelpout, Burrard Inlet, B.C.)
(10): 2754 (& size of steelhead trout, Babine R., B.C.)
(11): 3073 (derivation of average lengths of different fish age-groups)
(12): 3133 (& age distribution, cod off SW Nfld.)
CNS 27 (composition of 1967 B.C. commercial sockeye, chum, & pink salmon catches)
T 94–97 (frequency data, Nfld. herring, 1964–65 to 1967–68)
105 (B.C. commercial groundfishes)
108 (rock sole, N Hecate Strait, B.C.)
109 (yellowfin sole, Hecate Strait, B.C.)
139 (& age–length ratios, Gulf of St. Lawrence herring)
S 1302 (composition of chum salmon in open N Pac. Ocean)
1316 (& size & recruitment comparisons for Scotian Shelf haddock)
1317 (salmon from banks & deeps off Nfld.)
1318 (determination, validation, & composition, W Nfld. cod stock)
A 138 (queen crab)

Age determination (*see* Fins; Marking; Otoliths; Scales, fish; Tagging)

Aggregation (*see* Schooling)

Aggression (*see* Behaviour)

Aglantha digitale (a medusa)
J 26(6): 1485 (ecology, et..., Ogac L., Baffin Is.)

Agonidae
J 26(6): 1467 (standardization of bony plate terminology)

Agonus acipenserinus (*see* Poacher, sturgeon)
decagonus (*see* Poacher, Atlantic sea)

Aiken, David Edwin
A 135 (crustacean molt cycle)

Alanine (*see* Acids, amino)

Alaska (*see* Alaska, Gulf of; Bristol Bay)

Alaska, Gulf of
J 26(8): 1985 (demersal fishes exploratory survey)

Alburnus alburnus (*see* Bleak)

Alberta (*see also* Beaver Lake)
J 26(2): 325 (fishes distribution in southern)
(6): 1439 (fishes distribution re Missouri–Saskatchewan R. divide)

Alcohol, isopropyl (*see* Isopropanol)

Alderice, Donald Francis
T 100 (flathead sole embryonic development)

Alewife (*Alosa pseudoharengus*)
J 26(3): 597 (F) (retinal structure re activity, etc.)
B 151(F) (smoking & canning)

Algae (*see also* Seaweeds)
J 26(8): 2003 (production & community respiration in Marion L. sediments, B.C.)
(10): 2760 (bacterial flora of 6 genera for feeding quahaug & Atl. oyster larvae)
(12): 3101 (blooms after each fertilization of a lake)

Algonquin Park, Ont.
J 26(4): 871 (*Diphyllobothrium* cestode transmission to lake trout)

Alleles (*see* Genes; Heredity; Phenotypes; Transferrins)

Allen, Kenneth Radway
J 26(1): 179 (exploited populations estimation)
(6): 1429 (ecology of stream fishes: a review)
(9): 2267 (application of Bertalanffy growth equation)
S 1334 (salmonid populations in streams)

Allergy
B 168 : 4 (man, to shellfish)

Alligatorfish (*Aspidophoroides monopterygius*)
J 26(3): 597 (F)(retinal structure re activity, etc.)

Alosa pseudoharengus (*see* Alewife)

Alverson, Dayton Lee
J 26(8): 1985 (exploratory fishing methods)

Ames, Warren Alby
J 26(1): 15 (isozymes in sockeye sera)

Amino acids (*see* Acids, amino)

Aminotransferases (*see* Enzymes; Transferrins)

Ammodytes dubius (*see* Sand lance (*Ammodytes* spp.))
hexapterus (*see* Sand lance, Pacific)
Ammodytes spp. (*see* Sand lance)

Ammonia
S 1341 (re eutrophication of inlet extension of Victoria harbour, B.C.)

Ampelisca abdita (an amphipod)
J 26(6): 1415 (re community concept)

Amphipoda
J 26(2): 361 (study of *Haustorius canadensis, Neohaustorius biarticulatus, & Acanthohaustorius millsi* from Cape Cod, Mass.)
(3): 683 (Arctic & Atl. N America *Anonyx* taxonomy)
(4): 909 (*Gammarus* as intermediate host *Pomphorhynchus laevis* parasitic acanthocephalan)
(5): 1321 (study of *A. millsi, Parahaustorius longimerus, & Protohaustorius deichmannae* from Cape Cod)
(6): 1415 (*Ampelisca abdita* re community concept)
(8): 2016 (partitioning community respiration in a lake sediment)
(9): 2283 (physiological tolerances & behaviour responses of *H. canadensis, N. biarticulatus, A. millsi, Pr. deichmannae, & Pa. longimerus* to 5 environmental factors)
(9): 2403 (as blackbelly eelpout feed)

A 133 (general caloric value)

Amylopectin
S 1270 (possible significance of accumulation in *Clostridium botulinum* cytoplasm)

Anabaena (algae)
J 26(12): 3101 (blooms after fertilization of a lake)

Analysis, proximate (*see* Composition, chemical)

Analysis methods (chemical) (*see also* Composition, chemical)
J 26(6): 1664 (carbon estimation dichromate reagent instability)
(7): 1823 (1α-hydroxycorticosterone)
(7): 1959 (caloric content of marine sediments)
(9): 2345 (formula for calculating caloric content of zooplankton biomass)
(9): 2394 (dry extraction of fat from fresh fish)
(9): 2449 (copper in fresh waters of varying hardness)
(11): 3055 (toxic pollutants in kraft mill effluents)
B 168 : 5 (for paralytic shellfish toxin)
S 1265 (flame ionization detector, for organic compounds)
1339 (for fluoride determination in biological samples, e.g. fish protein concentrate)

Analysis methods (mathematical) (*see* Mathematical treatment)

Anarhichas lupus (*see* Wolffish, Atlantic)

Anatomy (*see* Histology; Morphology)

Anchovy, northern (*Engraulis mordax*)
J 26(3): 557 (particulate & filter feeding)
(11): 2843 (role in Pac. sardine ecology: mathematical treatment)

Anctil, Michel
J 26(3): 597(F) (retinal structure of teleosteans)

Anderson, George Cameron
S 1355 (NE Pac. Ocean nitrate)

Anderson, John Murray
J 26(1): 93 (Atl. salmon activity)
S 1324 (DDT effects on brook trout)

Anderson, Margaret Lillian
J 26(10): 2727 (protein in frozen cod muscle re free fatty acids)

Anderson, Roy Clayton
J 26(4): 849 (*Cystidicola* revision)

Androgens (*see* Hormones)

Anemia
J 26(1): 111 (from folic acid deficiency in coho salmon feed)

Anemone, deepsea
J 26(1): 145 (zinc content)

Anenterotrema spp. (digenetic trematodes)
J 26(4): 845 (special feeding modes)

Anglemouth, veiled (*Cyclothone microdon*)
J 26(10): 2692 (S of La Have Bank, N.S.)

Angling (*see also* names of sport fishes, e.g. Trout; Salmon)
T 130 (catches & weights of Atl. salmon in Nfld. streams)

Anguilla rostrata (*see* Eel, American)

Animal feed (*see* Feedstuff)

Annelids (*see also* subdivisions)
J 26(5): 1273 (in Atl. cod & haddock feed)

Anonyx (amphipods)
J 26(3): 683 (taxonomy of arctic & Atl. N American)

Anoplarchus purpurescens (*see* Cockscomb)

Anoplopoma fimbria (*see* Sablefish)

Anoxia (*see* Oxygen, dissolved)

Antia, Naval Jamshedji
J 26(5): 1185 (salmon skin purines & pteridines)

Antibiotics
J 26(5): 1263 (tetracycline marking of sockeye salmon fingerlings)

Antibodies (*see* Immunology)

Anticholinesterase (*see* Choline; Enzymes)

Antifouling treatments
T 119 (for ships hulls)

Antimora rostrata (*see* Cod, longfin)

Antioxidants
J 26(9): 2299 (re marine muscle lipids oxidation)

Antipollutant agent (*see also* Pollution)
S 1291 (nitrilotriacetic acid (NTA) for protecting fish from zinc & copper in waters)

Aorta (*see* Heart)

Apeltes quadracus (*see* Stickleback, fourspine)

Aplodinotus grunniens (*see* Sheepshead)

Apodichthys flavidus (*see* Gunnel, penpoint)

Apollonio, Spencer
J 26(8): 1969 (glass shrimp breeding & fecundity)

Apparatus; Equipment (*see also* names of types of fishing gear)
J 26(1): 21 (for response of smallmouth bass to shade)
(1): 63 (for inducing hypoxial stress in coho salmon embryos and fry)
(1): 93; (11): 2807 (fish respirometer)
(1): 133 (fry trap for estimating salmonid survival)
(1): 154 (for precise temperature control of fish refrigeration)
(2): 279 (trap for river benthic invertebrates)
(2): 361 (sand sampler)
(2): 389 (for Dungeness crab larvae culture)
(3): 583 (for Atl. cod odour perception re feeding)
(3): 687 (for testing rainbow trout bottom colour selection)
(4): 741 (for laboratory maintenance of cestode-infected sticklebacks)
(5): 1199 (holder for examining fin rays for aging)
(6): 1378 (spinner culturer for cells to detect water pollution)
(6): 1647 (for measuring fish larvae sustained swimming ability)
(6): 1685 (emergence trap for stream insects collection)
(7): 1847 (for aortic catheterization of trout)
(7): 1948 (vertical plankton & water sampling)
(7): 1956 (experimental tank to simulate reservoir conditions)
(8): 2005 (lake sediment sampler)
(8): 2227 (simple stream tank simulating a rapids environment)
(8): 2240 (new type of zooplankton & ichthyoplankton sampling net)
(8): 2257 (hand shears for heading & gutting capelin)
(9): 2363 (for bioenergetics experiments)
(9): 2523 (refrigerating sea water for improving scallop meats keepability)
(9): 2527 (hooks for deepsea line fishing)
(10): 2581 (bottom corer for sampling benthos & sediments)
(10): 2751 (bottom sediment sampler attached to trawl board)
(10): 2765 (liquid-nitrogen-cooled die for branding salmon & trout)
(11): 3083 (detector for magnetized wire salmon tags)
B 151(F) (for processing freshwater fishes products)
CNG 87 (experimental prawn traps)
CVG 42 (salmon-canning & herring-pump waste water clarification & solids recovery)
T 102 (used in cubmarine)
S 1269 (ultrasound production for parasite detection in fish)
1274 (mercury dispenser)
1296 (for tagging salmon smolts with aluminum staples)
1321 (trap for collecting marine sediment-forming materials)
A 125 (economics of, for fish protein concentrate manufacture)
128 (condensation of CNG 87 above)
138 (for catching, handling, & processing queen crab)

Aprodon cortezianus (*see* Eelpout, bigfin)

Arai, Hisao Philip
J 26(4): 799 (new trematode from a cottid fish)
(9): 2319 (parasites of B.C. marine fishes)

Arctic, Canadian (*see also* specific localities, e.g. Baffin Is., Ogac Lake, *also* Arctic Ocean)
J 26(7): 1899 (Decapoda of Beaufort Sea E to Cambridge Bay)
(8): 2201 (white whale tagging, Hudson Bay)

Arctic Ocean (*see also* Arctic, Canadian; Beaufort Sea)
J 26(2): 305 (zooplankton biomass)

Arctica islandica (*see* Quahaug, Ocean)

Argentina, South America
J 26(4): 753 (Digenea trematodes from fishes)

Argentine, Atlantic (*Argentinia silus*)
J 26(4): 879 (trematodes in)
T 103 (in experimental otter-trawling)
S 1287 (*Lampritrema nipponicum* trematode parasite in)
A 119 (ICNAF 1967 Canadian research report)

Argentinia silus (*see* Argentine, Atlantic)

Argis dentata (a crangonid shrimp)
J 26(7): 1899 (W Canadian Arctic)
A 133 (caloric content)

Argyropelecus lynchus lynchus (*see* Hatchetfish, silvery)

Arie, Benzion
S 1344 (gaffkemia of lobsters)

Ariomma bondi
J 26(10): 2769 (first Canadian record: Gulf of St. Lawrence)

Arita, George Shiro
J 26(12): 3262 (*Eumicrotremus orbis* sexual dimorphism)

Artedius fenestralis (*see* Sculpin, padded)
harringtoni (*see* Sculpin, scalyhead)

Artemia salina (*see* Shrimp, brine)

Arteriosclerosis
J 26(9): 2425 (in carp)

Arthropods (*see also* classifications and species names)
J 26(1): 145 (zinc content)

Artsob, Harvey
J 26(12): 3259 (infectious pancreatic necrosis in salmonids)

Ash (*see* Mineral content)

Ashley, L. E.
J 26(8): 2215 (infection of English sole)

Aspartate (*see* Acids, amino)

Aspidophorides monopterygius (*see* Alligatorfish)

Assay methods (*see also* Analysis methods (chemical))
J 26(11): 3055 (for toxic pollutants in kraft mill effluent)
B 168 : 5 (for paralytic shellfish toxin)

Associations (biological) (*see also* Communities)
J 26(10): 2703 (between seaweeds, Halifax Co., N.S.)
B 169 : 168 (invertebrates & algae re Pac. oyster beds, B.C.)

Astacene; Astaxanthin (*see* Pigments)

Asterias vulgaris (*see* Starfish, common)

Astoria Canyon (off mouth of Columbia River)
J 26(8): 2211 (ecology of yellowtail rockfish in)

Atheresthes stomias (*see* Flounder, arrowtooth)

Aulorhynchus flavidus (*see* Tube-snout)

Aurelia aurita (a jellyfish)
J 26(7): 1743 (experiments re feeding habits)

Australia
J 26(4): 787 (3 new hemiurid trematode genera from fishes)
S 1306, 1307 (copepods parasitic on fishes)

Azeotrope
J 26(7): 1923 (isopropanol–water, for lipids extraction in preparing fish protein concentrates)

B

Babine Lake and River, B.C. (*see also* Skeena River system)
J 26(2): 229 (sockeye salmon fry distribution, growth, & survival, from natural vs. artificial stream rearing)
(10): 2754 (steelhead trout age & size)

Bacillus (*see also* Bacteria)
J 26(10): 2659 (*B. mycoides* & *B. cereus* ingestion by oligochaetes in Toronto harbour sediments)
(10): 2760 (in culturing algal feed for rearing bivalve larvae)

Bacteria (*see also* names of some subclassifications)
J 26(1): 1 (lobster defense against *Gaffkya homari* infection)
(1): 47 (Atl. salmon intestinal, re DDT insecticide degradation)
(1): 115 (coho salmon & rainbow trout resistance to *Escherichia coli* & *Aeromonas salmonicida* endotoxins)
(2): 299 (bacteriovorous Protozoa, Puget Sound, Wash.)
(3): 629 (*Aeromonas salmonicida* bacteriophages)
(5): 1385; (9): 2503 (*Gaffkya* characteristics, culture, & growth)
(7): 1763 (*Thiocapsa* hydrogen sulfide-producing in B.C. meromictic lakes)
(8): 2003 (respiration in benthic sediments, Marion L., B.C.)
(9): 2311 (disinfection of trout eggs against *A. liquefaciens* transmission)
(9): 2535 (re Atl. salmon kidney disease & distinguishing between E & W Atl. Ocean populations)
(10): 2581 (bottom corer for sampling aquatic sedimentary)
(10): 2651 (flora of vacuum- vs. air-packaged fillets treated with EDTA preservatives)
(10): 2659 (sedimentary aerobic re tubificid oligochaetes in Toronto harbour)
(10): 2760 (of some algal feeds for rearing quahaug & Atl. clam larvae)
(12): 3217 (coliform counts re Nfld. cod & flounder commercial fillet production from fish variously handled at sea)
(12): 3165 (as zooplankton winter feed, Strait of Georgia, B.C.)
S 1303 (role in primary production from marine sedimentary organic debris)
1305 (biomass re marine feed of young Pac. salmons & trout)
1312 (use of choline or betaine for fatty acid synthesis in *Achromobacter cholinophagum*)
1326 (heterotrophic: role in converting organic particulate matter for primary productivity)

Bacteriophages
J 26(3): 629 (*of Aeromonas salmonicida*)

Baer, Jean Georges
J 26(4): 717 (*Diphyllobothrium pacificum* in Peru)

Baffin Island, N.W.T. (*see also* Ogac Lake)
J 26(1): 143 (observations on Greenland sharks)

Bagshaw, John Wyn
J 26(6): 1451 (*Polinices lewisi* boring organ)
S 1297 (salmon egg structure & enzymatic degradation)

Bailey, Merryll Marvin
J 26(5): 1289 (age & growth of longnose sucker)

Bait (*see also* Lures)
A 138 (for queen crab)

Baker, Craig Steven
J 26(5): 1371 (range of ocean whitefish & California halibut)

Baker, Dwight Lynds
J 26(9): 2517 (glyceraldehyde-3-phosphate re temperature effect)

Baker, Edgar George
J 26(2): 357 (salmon & trout pigmentation)

Baker, Jeremy Thomas Paine
J 26(11): 2785 (copper poisoning in the winter flounder)

Balaena glacialis (*see* Whale, black right)

Balaenoptera acutorostrata (*see* Whale, minke)
borealis (*see* Whale, sei)
musculus (*see* Whale, blue)
physalus (*see* Whale, fin)

Balanus (*see* Barnacle)

Ball, Ian Raymond
J 26(2): 221 (*Dugesia lugubris* in N American fresh waters)

Bams, Robert Abraham
S 1333 (sockeye salmon)

Bankia setacea (*see* Shipworms)

Banse, Karl
J 26(10): 2595 (Acrocirridae n.fam.)

Barb, Schuberti (*Barbus sachsi*) (tropical cyprinid)
J 26(8): 2250 (laboratory host for cestode culture)

Barbus sachsi (*see* Barb, Schuberti)

Barlow, John
J 26(8): 2101 (lobster molt serum protein)

Barnacle (*Balanus*)
B 168 : 30 (*B. cariosus* occasional toxicity in B.C.)

Barracudina, white (*Notolepis rissoi krøyeri*)
J 26(10): 2691 (recent catches off N.S.; diurnal depth distribution)

Barrow Lake, Alta.
J 26(7): 1934 (differentiation between *Coregonus artedii* & *C. zenithicus*)

Bartnik, Victor George
J 26(8): 2227 (simulating rapids environment)

Baslow, Morris Henry
J 26(8): 2208 (Pac. marine toxins: ciguatoxin not in vivo anticholinesterase)

Bass, largemouth (*Micropterus salmoides*)
J 26(10): 2643 (oxygen metabolism re body weight)

Bass, smallmouth (*Micropterus dolomieui*)
J 26(1): 21 (response to shade)

Bass, white (*Roccus chrysops*)
J 26(8): 2173 (open-water orientation re homing, as determined by ultrasonic tracking methods)

Bathylagus euryops (*see* Blacksmelt, goitre)

Batoosingh, Edward
J 26(10): 2581 (modified bottom sampler corer)

Bay *of*... (*see* name *of* bay)

Beamish, Frederick William Henry
J 26(11): 2807 (oxygen consumption *of Tilapia nilotica* re swimming speed & salinity)

Beamish, Richard James
J 26(3): 633 (white sucker age)

Beardfish (*Polymixia lowei*)
J 26(10): 2697 (first Canadian record; extends range to NE)

Beaufort Sea
J 26(7): 1899 (Decapoda)

Beaver Lake, Alta.
J 26(6): 1672 (aggregations *of* spottail shiners + yellow perch)

Beck, Brian
J 26(1): 143 (Greenland shark observations)

Beckett, James Stafford
S 1282 (swordfish catches size composition changes)
A 120 (longline lures for swordfish)

Bedford Basin, N.S.
T 120 (physical & chemical oceanography marine life)
S 1231 (current transport & deposition of sediment-forming materials)

Behaviour (*see also* Activity; Diel habits; Feed; Life history; Light, reactions to; Migration; Salinity, reactions to; Schooling; Sound, reactions to; Swimming; etc.)
J 26(1): 63 (hypoxial effect on coho salmon fry territoriality & size hierarchy)
(2): 361 (3 Haustoriidae amphipod species)
(3): 695 (brook trout & young Atl. salmon towards pesticides pollution)
(5): 1243 (cutthroat trout movements & homing)
(7): 1867 (stream dispersal of wild vs. hatchery-reared young Atl. salmon)
(8): 2061 (reproductive, of blackspotted stickleback)
(9): 2283 (responses of 5 haustoriid amphipod species to 5 environmental factors)
(12): 3252 (spawning, western brook lamprey)
A 136 (of fishes as observed from submarine)

Bell, Gordon Russel
S 1297 (salmon egg structure & enzymatic degradation)

Bella Coola River, B.C.
J 26(4): 813 (parasites of early sea pink salmon from)

Benthos (*see also* Epibenthos)
J 26(1): 55 (infauna standing crop composition, Puget Sound & outer coast of Wash.)
(2): 279 (benthic invertebrates upstream river movements)
(2): 299 (bacteriovorous Protozoa, Puget Sound, Wash.)
(3): 701 (estuarine, killed by abnormally low salinity)
(6): 1540 (planktonic larvae ecology, Ogac L., Baffin Is.)
(8): 2003 (community respiration in Marion L. sediments, B.C.)
(10): 2581 (corer for sampling sedimentary)
(12): 3101 (in a lake after several fertilizations)

Benthosema glaciale (*see* Lanternfish, glacier)

Benville, Pete Edward, Jr.
J 26(12): 3209 (DDT on activity of glucose 6-P dehydrogenase in fish)

Berardius bairdi (*see* Whale, Baird's beaked)

Bering Sea (*see also* Bristol Bay)
J 26(8): 1985 (demersal fishes exploratory survey)

Bernard, Frank Rheinhold
J 26(1): 190 (*Mytilicola orientalis* in bivalves)
(6): 1451 (*Polinices lewisi* boring organ)
(8): 2230 (new septibranch species from E Pac.)
S 1315 (*Polinices lewisi* sexual dimorphism)

Beröe spp. (ctenophores)
J 26(6): 1535 (Ogac L., Baffin Is.)

Berst, Alfred Hewitt
J 26(2): 456 (Great Lakes rainbow trout)
(10): 2681 (fish shape & structure re selectivity of gillnets)

Bertalanffy growth equation or curve
J 26(1): 161 (comparison with Gompertz growth equation)
(9): 2267 (review of application to fisheries management problems)
(11): 3069 (formulation of, when growth rate is roughly constant)

Best, Edgar Allan
J 26(7): 1955 (flag rockfish range extension)
(9): 2351 (halibut transferrin systems)

Betaine
S 1312 (used in fatty acid synthesis by a bacterium)

Betts, John LeRoi
J 26(11): 3055 (tetrachloro-*o*-benzoquinone toxic to young salmon)

Bianchin, Donald Miles
T 132 (*G. B. Reed* groundfish cruise 69-2)

Bibliography
S 1267 (nematodes occurrence in salmonoid fishes)

Bideford River (estuary), P.E.I.
J 26(3): 701 (estuarine fauna mass mortality re low salinity)

Bidgood, Bryant Frederick
J 26(2): 456 (Great Lakes rainbow trout)

Biely, Jacob
T 114 (Atl. coast herring meals)

Big Garlic River, Michigan
J 26(11): 3077 (sea lamprey larvicides tests)

Bigg, Michael Andrew
J 26(2): 449 (clines in harbour seal)
B 172 : (B.C. harbour seal life history)

Bilinski, Edward
J 26(7): 1857 (trout muscle lipase)

Billi, James Lynn
J 26(6): 1459 (infectious pancreatic necrosis detection methods)

Bilton, Hebert Thomas
J 26(5): 1199 (pectoral fin rays re salmon age)
CNS 27 (age composition of 1965 B.C. sockeye, chum, & pink salmon)
T 133 (sockeye scale characteristics)

Bioenergetics
J 26(9): 2363 (young sockeye salmon)
S 1310 (changes in cortisol dynamics in sockeye salmon re sexual maturity)

Biomass (*see also* Benthos; Matter, particulate; Productivity, primary; Phytoplankton; Plankton; Zooplankton)
J 26(2): 305 (zooplankton re Arctic basin & East Greenland Current hydrography)
(9): 2345 (caloric & carbon equivalents of zooplankton)
(12): 3165 (of winter zooplankton & feed, Strait of Georgia, B.C.
S 1305 (of marine microorganisms re young Pac. salmons & trout feed)

Biosynthesis (*see also* Photosynthesis; Productivity, primary)
S 1272 (scallop phospholipids)
1286 (eulachon squalene)
1289 (salmon & trout inosinic & uridylic acids)
1312 (choline or betaine for fatty acid, in a bacterium)
1325 (of 1α-hydroxycorticosterone by elasmobranchs)
1346 (phospholipids by lobster)

Birds
J 26(4): 1103 (nematodes and other helminths from Australian gulls & terns)
T 122 (observed during experimental NW Atl. otter trawling)

Bishop, Daniel Magnus
J 26(9): 2299 (hematin compounds re rancidity)

Bishop, John Edward
J 26(2): 279 (benthic invertebrates)

Bivalves (*see also* Mollusca; *also* names of individual species, e.g., Clam; Mussel; Oyster; Scallop)
J 26(8): 2231 (description of 5 new NE Pac. species)
(9): 2403 (as blackbelly eelpout feed)

Blackbourn, David John
S 1294 (*Mesodinium rubrum* ciliate pigments)

Blackcod (*see* Sablefish)

Blackflies (*see* Simuliidae)

Blacksmelt, goitre (*Bathylagus euryops*)
J 26(10): 2692 (S of La Have Bank, N.S.)

Blackwood, Chesley MacKenzie
J 26(9): 2523 (scallop meat landed quality)

Bladder, swim (*see also* Swimming)
J 26(4): 849 (*Cystidicola* nematode infection, various N American fishes)
(4): 941 (sockeye salmon: invasion route by dracunculoid nematode)
(7): 1927 (purine source of silvery layer in pike, walleye, & channel catfish)
(8): 2077 (re buoyancy adjustment of Atl. & Pac. herring)
(8): 2093 (re buoyancy of Atl. salmon parr & smolt)
S 1299 (nematode parasites of Pac. salmons)
1299, 1300 (*Salvelinema walkeri* nematode parasite of coho salmon)

Blackland, Martin
A 134 (work of FRB Marine Ecology Laboratory)

Bleak (*Alburnus alburnus*)
J 26(11): 2795 (fecundity in River Thames, England)

Blepsias cirrhosus (*see* Sculpin, silver-spotted)

Bloater (*Coregonus hoyi*)
J 26(4): 849 (*Cystidicola* nematodes in swim bladder)

Blood; Blood constituents (*see also* Heart; Hematin; Hemoglobin; Respiration; Serum)
J 26(1): 111 (coho salmon anemia from folic acid deficiency in feed)
(2): 433 (morphology of 3 estuarine cyprinodontiform fishes)
(4): 1075 (hematazoic protozoan parasites of N.B. & New England marine fishes)
(5): 1392 (lobster hemolymph disposal of foreign proteins)
(5): 1397 (protein polymorphism in harp seals)

(7): 1823 (mineralocorticoid activity assay method for plasma steroids in skate)
(7): 1847 (aortic catheterization effects on brook trout hematology)
(8): 2101 (protein serum changes in molting & reproducing lobster)
(11): 2881 (constituents of largemouth & smallmouth buffalofish)
S 1300 (nematode parasite feeding on coho salmon swim bladder)
1308 (steroids binding by Atl. salmon & cod plasma proteins)
1344 (*Gaffkya homari* effects on lobster)

Blubber
J 26(10): 2561 (weight in white whales)

Bluegill (*Lepomis macrochirus*) (bluegill sunfish)
J 26(7): 1813 (temperature & body weight effects on endogenous nitrogen secretion)

Bonito, Pacific (*Sarda chiliensis*)
J 26(4): 713 (*Diphyllobothrium* parasite in Peruvian)

Bosmina (Cladocera)
J 26(8): 2135 (*B. longirostris* & *B. coregoni* horizontal distribution in L. Ontario)

Bothrimonus (*Diplocotyle*) (cestodes)
J 26(4): 975 (history, descriptions, synonymy, systematics)

Bottom sediments (*see* Sediments)

Bourne, Neil
J 26(9): 2527 (line fishing off B.C.)
(12): 3246 (*Eptatretus deani* from B.C.)
T 104 (scallop resources of B.C.)
118 (Masset, B.C., razor clam)

Boyce, Norbert Patrick Joseph
J 26(4): 813 (parasites of juvenile pink salmon)
(4): 893 (two hemiurid trematodes)

Braaten, Duane Ole
J 26(2): 339 (robustness of DeLury estimator)

Brachiella magna and *B. tetrici* (parasitic copepods)
S 1307 (new species, from Australian fishes)

Brachyisteus frenatus (*see* Perch, kelp)

Branding (*see* Marking)

Brawn, Vivien Mavis
J 26(3): 583 (cod feeding behaviour)
(8): 2077 (buoyancy of herring)
(9): 2345 (zooplankton biomass equivalents)
A 133 (food of cod)

Bream, white (*Abramis blicca*)
J 26(9): 2532 (polymorphic serum esterases suited for population analysis)

Brett, John Roland
J 26(9): 2363 (sockeye growth & composition)
A 118 (Pac. salmons: a review)

Brining
B 151(F) (freshwater fishes for smoking)

Brinkhurst, Ralph Owen
J 26(10): 2581 (modified bottom sampler corer)
(10): 2659 (some tubificid–sediment interactions)

Bristol Bay, Alaska (*see also* Bering Sea)
J 26(3): 655 (variance components in estimating sockeye salmon egg deposition potential)

British Columbia (*see also* names of localities)
J 26(7): 1727 (synopsis & key to Ophiuroidea of S)
(7): 1763 (limnology of 4 meromictic small lakes)
(8): 1985 (demersal fishes exploratory survey)
(9): 2319 (parasites of various marine fishes)
B 168 (paralytic shellfish poisoning in)
169 (Pac. oyster culture)
171 (marine mammals)
T 104 (scallop resources)
S 1328 (shrimp industry)
A 122 (whaling industry)

Brodie, Paul Frederick
J 26(8): 2201 (tagging white whales)
(10): 2561 (body size in white whales)

Brosme brosme (*see* Cusk)

Brown, Carolyn
J 26(10): 2760 (algal foods bacterial flora for rearing bivalve larvae)

Browning of fish flesh (Maillard browning)
A 130 (recent advances in overcoming)

Buchwald, David Glen
J 26(8): 2260 (*Triaenophorus crassus* in arctic lampreys)

Budd, J. C.
J 26(9): 2413 (survival of planted lake trout)

Buerkle, Udo
J 26(5): 1113 (auditory masking in cod)

Buffalofish, bigmouth (*Ictiobus cyprinellus*) (mullet)
J 26(11): 2881 (hematology)

Buffalofish, smallmouth (*Ictiobus bubalus*)
J 26(11): 2881 (hematology)

Bufo marinus (*see* Toad)

Buhler, Donald Raymond
J 26(12): 3209 (DDT on activity of glucose 6-P dehydrogenase in fish)

Bullhead, brown (*Ictalurus nebulosus*)
J 26(10): 2643 (oxygen metabolism re body weight)
B 151(F) (sausage)

Bullock, Wilbur Lewis
J 26(4): 1075 (marine fish hematozoa)

Buoyancy (*see also* Bladder, swim; Swimming)
J 26(8): 2077 (Atl. & Pac. herring adjustment mechanism)
(8): 2093 (seasonal changes in Atl. salmon parr & smolt)

Burbot (*Lota lota*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(7): 1927 (purine sources of skin silvering)
B 151(F) (smoked & canned flesh & liver)

Burnett, Cariene Doris
T 139 (Gulf of St. Lawrence herring catch statistics)

Burrard Inlet (outer), B.C.
J 26(9): 2403 (blackbelly eelpout biology)

Burrowing
J 26(2): 361 (habits of 3 Haustoriidae amphipod species)

Burt, Michael David Brunskill
J 26(4): 975 (biology of *Bothrimonus*)

Butler, David Gordon
J 26(3): 639 (eel renal physiology)
S 1337 (adrenalectomy of the eel)

Butler, Robert Lee
J 26(1): 21 (bass response to shelter)

Butler, Terrance Henry
J 26(10): 2751 (trawl-board sediment sampler)
S 1328 (B.C. shrimp fishery)

Buttkus, Hans
S 1314 (cysteine & methionine reaction)

C

Caballero y C., Eduardo
J 26(4): 957(F) (trematodes of Pac. fishes)

Caballero R., Guillermina
J 26(4): 957(F) (trematodes of Pac. fishes)

Caddisflies (*see* Trichoptera)

Caddy, John Frederick
S 1284 (Georges Bank scallop fishery)
A 136 (submersibles for fisheries research)

Calanoida (*see also* names of other genera)
J 26(1): 150 (*Acartia tonsa* & *Eurytemora affinis* culture in synthetic sea water)
(5): 1347 (chemical factors affecting *Euchaeta japonica* culture)
(6): 1537 (*Eurytemora americana*, Ogac L., Baffin Is.)
(10): 2543 (life cycle, seasonal abundance & vertical distribution of several species, Parry Sound, Ont.)

Calanus (*see also Limnocalanus*)
J 26(6): 1539 (*C. glacialis*, Ogac L., Baffin Is.)
(6): 1631 (young chum salmon growth on *C. plumchrus*)

Calaprice, John Robert
S 1335 (managed salmonid populations genetic & production factors)

Calcium compounds
J 26(2): 413 (cation concentration in Atl. salmon semen)
T 114 (calcium content of Atl. & Pac. herring meals)
S 1273 (partial molal volume of chloride, sulphate, bicarbonate, & nitrate in sea water)

Caligus (copepods)
S 1263 (taxonomy & nomenclature)

Caligus elongatus
J 26(4): 1013 (distribution, morphology, hosts, & taxonomy re *C. rapax*)

Caligus lacustris (*C. appendiculatus*)
S 1293 (application to legalize specific name *lacustris*)

Caligus longicaudatus
S 1263 (morphology)

Caligus rapax (*see elongatus*)

Callianassa californiensis (*see* Shrimp, ghost)

Callorhinus ursinus (*see* Seal, northern fur)

Caloric content
J 26(7): 1959 (chemical method for marine sediments)
(9): 2345 (formula for calculating from carbon & ash content of zooplankton biomass)
(9): 2363 (of young sockeye salmon re feed conversion efficiency)
T 114 (Canadian Atl. herring meals)
A 133 (of marine invertebrates fed on by Atl. cod)

Cameron T. W. M.
J 26(4): 713 (an appreciation of)

Campbell, James Scott
J 26(7): 1699 (brook trout world range)

Cancer borealis (*see* Crab, Jonah)
gracilis (*see* Crab, graceful)
irroratus (*see* Crab, rock)
magister (*see* Crab, Dungeness)
productus (*see* Crab, rock)

Cannibalism
J 26(6): 1605 (*Cyclops bicuspidatus thomasi* copepodids)
(6): 1619 (coho salmon on their fry)

Canning; Canned products
J 26(2): 357 (enhancing flesh colour of trouts & pink salmon)
(3): 704 (nucleotides & related compounds in Arabian shrimp)
(8): 2234 (colour of canned Pac. salmons flesh vs. Atl. salmon flesh)
B 151(F) (freshwater fishes)
168 : 50 (B.C. shellfishes: toxicity control)
169 : 138 (Pac. oyster products: fresh, smoked, stew)
CVG 42 (solids, oil, etc. recovery from salmon-canning waste waters)
43, 44 (chilling of salmon catch re quality of canned product)
T 101 (experimental, of ocean quahaug)
S 1309 (colour sorting of raw coho & sockeye salmon re subsequent colour of canned)
A 138 (queen crab)

Canthaxanthin (*see* Pigments)

Cape Cod, Mass.
J 26(2): 361; (5): 1321 (study of 5 sand-burrowing amphipod species)

Capelin (*Mallotus villosus*)
J 26(3): 597(F) (retinal structure re activity, etc.)
(8): 2027, 2037 (chemical analyses, sizes, & lengths, of spawning Nfld., re commercial fishery potential)
(8): 2257 (special hand shears for heading & gutting)
B 151(F) (smoked canned)
CJG 16 (migrations of coastal, Trinity Bay, Nfld.)
A 119 (ICNAF 1967 Canadian research report on)

Capillaria thomascameroni (nematode)
J 26(4): 1103 (new species from an Australian bird)

Coranx crysos (*see* Runner, blue)

Carassius auratus (*see* Goldfish)

Carbon, organic (*see also* Productivity, primary)
J 26(9): 2345 (re calculation of caloric content of zooplankton biomass)

Carbon, particulate (*see also* Matter, particulate)
J 26(6): 1664 (instability of dichromate reagent for estimation of)

Cardiomya isolirata (septibranchid bivalve)
J 26(8): 2230 (new NE Pac. Ocean species)

Carotenoid pigments (*see* Chlorophylls; Pigments)

Carp (*Cyprinus carpio*)
J 26(6): 1439 (distribution in Canadian Missouri R. headwaters)
(9): 2425 (progressive changes in ventral aorta)
(10): 2643 (oxygen metabolism re body weight)
B 151(F) (smoking; sausage products)

Carpiodes cyprinus (*see* Sucker, quillback)

Carrothers, Percival John Godber
T 125 (otter trawl performance)
S 1281 (fish nets synthetic fibres)
A 129 (synthetic fibres used in fishing)

Carter, John Charteris Haig
J 26(10): 2543 (*Limnocalanus macrurus* & *Senecella calanoides* life cycles, and planktonic copepods in Parry Sound)

Carvey, Forrest Elwood, Jr.
J 26(8): 2211 (shelf rockfish feeding)

Casselman, John Malcolm
J 26(1): 175 (pike and muskellunge identification)

Castell, Charles Howell
J 26(9): 2299 (hematin compounds re rancidity)

Catalase
J 26(9): 2299 (as catalyst of marine muscle lipids oxidation)

Catchability
J 26(2): 339 (DeLury population estimator robustness)
(12): 3266 (diel activity judged by, for freshwater fishes)

Catches (*see also* Angling; Fisheries; Yield)
J 26(10): 2715 (check for maximum equilibrium, using catch statistics)
(11): 2843 (forecasting of Pac. sardine, re predator & prey ecology: mathematical model)
(12): 3133 (& catch per unit effort, of SW Nfld. cod)
B 171 : 50 (B.C. whales, 1905–67)
CJG 16 : 25 (cod, off Labrador, 1936–68)
16 : 27 (groundfish, Nfld., 1953–68, & details for 1968)
CNS 27 (age composition of B.C. commercial sockeye, chum, & pink salmon, 1967)
28 (Canadian & American trawling, from grounds off B.C., 1954–65)
T 86 (cod & haddock trawlings, on Scotian Shelf & Georges Bank, 1965)
103, 122 (fishes etc. taken during Atl. otter-trawl surveys, 1967 & 1968)
108 (B.C. rock sole, 1945–64)
113 (Pac. ocean perch, experimental, off W coast Vancouver Is.)
117, 131 (catch & effort statistics, B.C. trawl fishery, 1968)
139 (gulf of St. Lawrence herring, 1933–68)
A 123 (Nfld. salmon)
138 (queen crab, on Canadian Atl. coast)

Catfish, channel (*Ictalurus punctatus*)
J 26(6): 1439 (distribution in Canadian Missouri R. headwaters)
(7): 1927 (purine sources of skin silvering & swim bladder silvery layer)

Catostomus catostomus (*see* Sucker, longnose)
commersoni (*see* Sucker, white)
platyrhynchus (*see* Sucker, northern mountain)

Caulolatilus princeps (*see* Whitefish, ocean)

Centrolophus niger (*see* Ruff, black)

Cephalopoda
S 1327 (Canadian, with synopsis)

Ceratoscopelus maderensis (*see* Lanternfish, horned)

Ceriodaphnia lacustris (a cladoceran)
J 26(8): 2135 (horizontal distribution in L. Ontario)

Cestoda (tapeworms)
J 26(4): 717 (*Diphyllobothrium pacificus* in sea lions & man, Peru)
(4): 741 (*Schistocephalus solidus* culture & growth rate)
(4): 805 (various, in Nfld. fishes)
(4): 813 (*Phyllobothrium* sp. of pink salmon early sea life)
(4): 821, 833 (*Triaenophorus nodulosus* biology & infection dynamics in yellow perch)
(4): 833 (of yellow perch, Bay of Quinte, L. Ontario)
(4): 871 (*Diphyllobothrium* transmission to lake trout)
(4): 947 (histology of 3 *Diphyllobothrium* cestode species, including *D. cameroni* new species)
(4): 975 (*Bothrimonus* history, description, synonomy, & systematics)
(4): 1037(F) (4 tetrarhynchian (1 new genus) from U.S. Atl. coast sharks)
(8): 2250 (maintenance of *Ligula intestinalis* life cycle in laboratory)
(9): 2319 (list of species found in B.C. marine fishes)
T 134 (as indicator species for distinguishing Atl. salmon stocks)
S 1354 (rostellar hooks development in *Paricterotaenia paradoxa*)

Catacea (*see also* Dolphin; Porpoise; Whale)
B 171 (of B.C.)

Chaetoceros curvisetus (a phytoplankter)
J 26(6): 1625 (chlorophylls extraction procedure)

Chaetognatha (*see Sagitta*)

Chandler, Ross Allan
T 101 (uses of ocean quahaugs)

Char, arctic (*Salvelinus alpinus*)
J 26(4): 975 (*Bothrimonus* cestode biology in)

Char, Dolly Varden (*see* Dolly Varden)

Chaston, Ian
J 26(8): 2165 (brown trout feeding pattern)

Chatham Sound, B.C.
J 26(8): 2219 (juvenile Pac. salmons feed)

Chauliodus macouni (*see* Viperfish, fanged)
sloani (*see* Viperfish)

Chaulk, Raymond
T 96 (Nfld. herring sampling data, 1966–67)
97 (Nfld. herring sampling data, 1967–68)

Checklist (*see also* Lists)
J 26(4): 793 (nematodes from Sabah fishes, amphibians, & reptiles)

Chen, Maynard Yingnan
J 26(9): 2521 (hermaphroditism in lake whitefish)

Cherrington, Alan Douglas
J 26(1): 47 (DDT degradation by salmon)

Cheticamp River, N.S.
T 115 (physical oceanography of estuary)

Chew, Kenneth Kendall
J 26(8): 2245 (*Mytilicola orientalis* fecundity)

Chignik Lakes, Alaska
J 26(2): 405 (4 threespine stickleback phenotypes)

Chilling (*see* Ice; Refrigeration; Sea water, refrigerated)

Chimera, deepwater (*Hydrolagus affinis*)
J 26(2): 311 (parasitic copepod on cornea)

Chionoecetes opilio (*see* Crab, queen)

Chironomidae (*see also* Diptera)
J 26(8): 2016 (partitioning community respiration in a lake sediment)
(10): 2581 (bottom corer for sampling)
B 170 (description, morphology, taxonomy, distribution, etc. of Nearctic N American, including 33 new species)
T 124 (classification of Nearctic)

Chitonotus pugetensis (*see* Sculpin, roughback)

Chlamys hastata hericia (*see* Scallop, spiny)
rubida (*see* Scallop, pink)

Chlebeck, Anne Marie
J 26(11): 2881 (hematological studies of 2 buffalofishes)

Chlorophyceae (*see also* Seaweeds)
J 26(10): 2703 (of Halifax Co., N.S.)

Chlorophylls (*see also* Algae; Phytoplankton; Productivity, primary)
J 26(6): 1625 (optimal extraction conditions from 5 marine phytoplankton species; correction on J 26(8): 2264)
(11): 2959 (salinity & illumination effects on, in *Monochrysis lutheri* flagellate)
T 110 (Strait of Georgia: seasonal variations of *a*, 1965–67)
S 1294 (*a* & *c* in *Mesodinium rubrum* ciliate)
1295 (*a* as index of oceanic primary & secondary production)
1341 (*a* re eutrophication of inlet extension of Victoria harbour, B.C.)

Chloropthalmus agassizi (*see* Greeneye, shortnose)

Cholesterol (*see* Sterols)

Choline and derivatives
J 26(8): 2195 (acetylcholinesterase activity of insecticide-treated rainbow trout larvae)
(8): 2208 (anticholinesterase activity of toxin from moray eel)
S 1312 (used in fatty acid synthesis by a bacterium)

Chondracanthus narium (parasitic copepod)
J 26(11): 3043 (new species, from lingcod nasal cavity)

Chondrus crispus (*see* Irish moss)

Choquette, Laurent Paul Emile
J 26(4): 713 (T. W. M. Cameron appreciation)

Chromatography, gas–liquid and column
S 1265 (flame ionization detector re)
1330 (procedure for separating triglycerides from fatty acids)
1331 (temperature effects re separation of multiple-branched fatty acid esters and ketones)
1351 (cis & trans isomerism effect on monoethylenic fatty acid isomers separation)

Chromium compounds
J 26(6): 1664 (carbon estimation dichromate reagent instability)

Chromobacterium spp.
J 26(10): 2659 (ingested by oligochaetes in Toronto harbour sediments)

Chromosomes (*see also* Cytology; Genes; Heredity)
J 26(3): 543 (re *Pseudocalanus* size variation & polyteny, Ogac L., N.W.T.)

Chrosomus eos (*see* Dace, northern redbelly)
neogaeus (*see* Dace, finescale)

Chrysophyceae (*see also* Seaweeds)
J 26(10): 2703 (*Phaeosaccion collinsii*, Halifax Co., N.S.)

Chua, Kian Eng
J 26(10): 2581 (modified bottom sampler corer)
(10): 2659 (some tubificid–sediment interactions)

Chub, flathead (*Platygobio gracilis*) (*Hybopsis gracilis*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Chub, lake (*Couesius plumbeus*)
J 26(2): 325 (S Alta. distribution)

(6): 1439 (distribution in Canadian Missouri R. headwaters)
B 151(F) (smoking; canning)

Ciguatoxin (*see* Toxicants)

Ciliata (*see also* subclassifications)
J 26(10): 2669 (*Entodiscus borealis* in intestine of sea urchin)
S 1294 (*Mesodinium rubrum* pigments)

Cirratulidae (Polychaeta Sedentaria)
J 26(10): 2595 (*Acrocirrus* & *Macrochaeta* removed to new family Acrocirridae)

Cisco (*see* Herring, lake; Tullibee)

Cisco, longjaw (*Coregonus alpinae*)
J 26(4): 849 (*Cystidicola* nematodes in swim bladder)

Cisco, shortjaw (*Coregonus zenithicus*)
J 26(7): 1934 (differentiation from *C. artedii*, Barrow L., Alta.)

Cisco, shortnose (*Coregonus reighardi*)
J 26(4): 849 (*Cystidicola* nematodes in swim bladder)

Citharichthys stigmaeus (*see* Sanddab, speckled)

Cladocera (*see also* certain species)
J 26(8): 2135 (composition & horizontal distribution, L. Ontario)
(9): 2459 (seasonal composition, distribution, & abundance, L. Erie)
(12): 3101 (of Crecy L., N.B.)

Claggett, Freddie Gene
CVG 42 (salmon canning waste water clarification)

Clam, bent nosed (*Macoma nasuta*)
B 168 : 30 (negative toxicity in B.C.)

Clam, butter (*Saxidomus giganteus*)
B 168 : 21 (anatomy and toxicity tests, re paralytic shellfish poisoning in B.C.)

Clam, cockle (*Clinocardium nuttalli*)
B 168 : 33 (toxicity tests, B.C.)

Clam, hard (*see* Quahaug)

Clam, hooked surf (*Spisula falcata*)
B 168 : 29 (no record of toxicity in B.C.)

Clam, horse (*Tresus capax*)
B 168 : 33 (toxicity tests, B.C.)

Clam, Manila (*Venerupis japonica*)
B 168 : 33 (toxicity tests, B.C.)

Clam, milky venus (*Compsomyax subdiaphana*)
B 168 : 30 (negative toxicity in B.C.)

Clam, native little-neck (*Protothaca staminea*)
B 168 : 33 (toxicity tests, B.C.)

Clam, razor (*Siliqua patula*)
T 118 (population studies, Masset, B.C.)

Clam, ringed lucina (*Lucinoma annulata*)
B 168 : 31 (negative toxicity acquisition from *Gonyaulax*)

Clam, soft shell (*Mya arenaria*)
J 26(3): 701 (resistance to abnormally low estuarine salinity, P.E.I.)
B 168 : 33 (toxicity tests, B.C.)

Clam drill (*Polinices lewisi*) (*see also* Snail, moon)
J 26(6): 1451 (accessory boring organ histology)
S 1315 (sexual dimorphism)

Clams (Atlantic) (*see also* Clam drill)
J 26(3): 701 (*Macoma balthica*, etc. severe mortality due to unusually low P.E.I. estuarine salinity)

Clams (Pacific)
J 26(8): 2230 (5 new species)
B 168 : 30 (susceptibility to acquisition of toxicity from *Gonyaulax*, in B.C. waters)

Clarification
CVG 42 (of salmon-canning & herring-pumping waste waters)

Clarke, William Craig
S 1337 (adrenalectomy of the eel)

Classification (*see also* Taxonomy)
T 124 (of Nearctic Chironomidae)

Clavellodes pterobranchiata (parasitic copepod)
S 1307 (new species, from Australian fishes)

Clayton, James Wallace
J 26(11): 3049 (longnose & blacknose dace & hybrid isozymes)

Climate (*see also* Storms)
T 98 (Little Codroy R., Nfld.)
130 (as factor re Nfld. streams productivity)

Clinocardium nuttalli (*see* Clam, cockle)

Clinocottus analis (*see* Sculpin, woolly)

Cliona celata (*see* Sponge, boring)

Clostridium botulinum
S 1270 (amylopectin accumulation in cytoplasm of)

Clupea harengus (*harengus*) (*see* Herring, Atlantic
(*harengus*) *pallasi*(*i*) (*see* Herring, Pacific)

Clymenella torquata (polychaete)
T 116 (observations, particularly on egg production)

Cnidospora
J 26(4): 725 (review of fish parasitization, re Sporozoa)

Cobalt compounds
J 26(5): 1347 (re calanoid copepods culture)
T 114 (cobalt content of Atl. & Pac. herring meals)

Cockle (*see* Clam, cockle)

Cockscomb (*Anoplarchus purpurescens*)
J 26(9): 2319 (parasites, B.C.)

Cod, Atlantic (*Gadus morhua*)
J 26(3): 583 (feeding behaviour)
(5): 1113 (auditory masking & the critical sound band)
(5): 1273 (feed, Gulf of St. Lawrence & N.S. Banks)
(9): 2299 (promoters & inhibitors of muscle lipids oxidation)
(10): 2621 (glycolytic & nucleotide changes in critical freezing zone of prerigor muscle)
(10): 2727 (free fatty acids reaction with muscle protein iced then frozen)
(12): 3133 (fishery & biology off SW Nfld.)
(12): 3217 (bacteriology of commercial fillets from fish frozen at sea & thawed in water)
(12): 3271 (quality evaluation of frozen vs. freeze-dried steaks)
(12): 3242 (fibrous & cystic lesions in ovaries of aged)
CJG 16: 25 (Labrador landings, 1936–68)
16: 27 (Nfld. landings, 1953–58)
T 86 (trawl catches, Scotian Shelf & Georges Bank, 1965)
S 1290 (deterioration & storage life of frozen fish & fillets)
1308 (blood plasma proteins binding of steroids)
1318 (biology & fishery of W Nfld. stock)
1342 (aminotransferases in eggs & sperm)
1349 (muscle tropomyosin isolation by heat treatment)
1352 (encyclopedia article on biology, fishery, catches, processing, products, etc.)
A 119 (ICNAF 1967 Canadian research report on)
124–126 (use for fish protein concentrate)
133 (feed)
136 (underwater behaviour observations from cubmarine)

Cod, black (*see* Sablefish)

Cod, longfin (*Antimora rostrata*)
J 26(9): 2527 (in deepsea line fishing off B.C.)

Cod, Pacific (*Gadus macrocephalus*)
J 26(8): 1985 (stock & yield forecast, N Pac. Ocean)
(9): 2319 (parasites, B.C.)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
CVG 41 (weight changes during holding in refrigerated sea water vs. ice)
T 105 (life history, feed, etc.)
117, 131 (B.C. commercial trawl landings, 1968)
135 (length–weight relations)

Codworm (*Phocanema decipiens*) (nematode)
J 26(4): 935 (moulting cycle feeding behaviour)

Coelenterates (*see also* Jellyfishes)
J 26(1): 145 (deepsea anemone zinc content)
A 133 (caloric content of Duva multiflora)

Cold storage (*see* Refrigeration)

Coleoptera (*see also* Insects, aquatic)
J 26(5): 1157 (feed, habits, ecology, in small Que. stream)
(12): 3101 (of Crecy L., N.B.)

Collette, Bruce B.
J 26(5): 1375 (Arctic shanny record Massachusetts Bay)

Collins, Curtis Allan
T 106 (Ocean Station P oceanographic data time distribution)

Colour (*see* Pigments; Vision, reactions to)

Colton, John Bowne, Jr.
J 26(10): 2746 (Gulf of Maine 1968 temperature conditions)

Communities (*see also* Associations)
J 26(5): 1157 (aquatic insect, in small Que. stream)
(6): 1415 (concept in marine zoology)

Competition
J 26(1): 63 (coho salmon fry, re earlier hypoxial stress)

Composition, chemical (*see also* Analysis methods, chemical)
J 26(8): 2027, 2037 (beach-spawning capelin, Nfld.)
(8): 2234 (lipids & carotenoids content of Atl. & Pac. salmons)

(9): 2363 (fingerling sockeye salmon re temperature & rations)
(10): 2669 (*Syndesmis franciscana* turbellarian)
(11): 2823 (changes in steelhead trout during parr-to-smolt transformation)
(11): 2969 (*Parapenaeus* Atl. shrimps)
B 151(F) (Great Lakes fishes fillets)
169 : 135 (Pac. oyster, B.C.)
T 114 (Canadian Atl. herring meals)
130 : 217 (of many Nfld. streams)
S 1273 (partial molal volumes of 16 salts in sea water)
A 124, 125 (fish protein concentrates)

Compsomyax subdiaphana (*see* Clam, milky venus)

Computer programming (*see also* Mathematical treatment of data)
J 26(1): 131 (for allometric weight–length relations)
(1): 179 (for estimating exploited populations)
T 92 (equilibrium yield per recruitment of a fish stock)
112 (for multiple discriminant analysis)
121 (for analysis of feeding heterogeneities re predator body size)
129 (statistical analysis of fish length-frequency data)

Condition
J 26(6): 1473 (re wild brook trout fingerlings overwinter survival)
(8): 2003 (of beach-spawning capelin, Nfld.)
(8): 2077 (of Atl. & Pac. herring re buoyancy)
(8): 2093 (of Atl. salmon parr & smolt re buoyancy)
(11): 2823 (of steelhead trout during parr-to-smolt transformation)
B 169 : 115 (Pac. oyster, B.C.)
T 79 (re Atl. herring fat content & season)
S 1288 (serum protein concentration of hemolymph as index of lobster)

Connors, Mary Patricia
T 125 (otter trawl performance)

Contracaecum (nematodes)
J 26(4): 793 (in Sabah fishes)
(9): 2319 (in B.C. marine fishes)

Control (*see also* Management)
B 168 (of clam digging in B.C., re paralytic shellfish poisoning)

Copepoda (*see also* Calanoida; *Cyclops*; *Oithona* and other genera)
J 26(1): 143 (parasitic *Ommatokoita elongata* on Greenland shark cornea)
(1): 150 (calanoid larvae culture in synthetic sea water)
(1): 190; (8): 2245 (parasitic *Mytilicola orientalis* in Pac. coast oyster & mussel)
(2): 311 (4 Lernaeopodidae species parasitic on Nfld. & W Greenland fishes)
(4): 741 (hosts of *Schistocephalus solidus* cestode)
(4): 805 (*Schistobranchia ramosus* from Nfld. thorny skate)
(4): 833 (*Ergasilus caerulens* on yellow perch gills)
(4): 921 (*Phrixocephalus cincinnatus* biology)
(4): 997 (*Ergasilus arthrosis* new species; *Ergasilus* genus taxonomy)
(4): 1013 (*Caligus elongatus* distribution, hosts; taxonomy re *C. rapax*)
(5): 1347 (*Euchaeta japonica* culture chemical factors)
(8): 2016 (partitioning community respiration in a lake sediment)
(8): 2135 (composition & horizontal distribution, L. Ontario)
(8): 2221 (in juvenile Pac. salmons feed)
(9): 2319 (list of species parasitic to B.C. fishes)
(9): 2459 (seasonal distribution, composition, & abundance, L. Erie)
(10): 2543 (life cycle, seasonal abundance, & vertical distribution of various, Parry Sound, Ont.)
(12): 3101 (of Crecy L., N.B.)
T 134 (*Salmincola salmoneus* as indicator for distinguishing Atl. salmon stocks)
S 1263 (*Caligus longicaudatus* description)
1295 (re critical indices of oceanic primary & secondary production)
1301 (*Praecidochondria galatheae* new genus & species parasitic on a Malayan fish)
1306 (*Shiinoa occlusa* new genus & species, parasitic on Australian fishes)
1307 (6 lernaeopodid (4 new species) & 1 naobranchiid parasitic on Australian fishes)

Copper compounds
J 26(9): 2299 (copper sulphate effect on marine muscle lipids oxidation)
(9): 2449 (chronic toxicity of fathead minnow to)
(11): 2785 (detailed tissues study of winter flounder subjected to copper sulphate)
B 169 : 145 (in Pac. oyster)
T 114 (copper content of Atl. & Pac. herring meals)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

119 (copper oxide in antifouling paints for ships hulls)
120 (in Bedford Basin waters, N.S.)
S 1291 (antipollutant agent for protecting fish from)

Coppermine River, N.W.T.
J 26(8): 2252 (broad whitefish age & growth)

Coregonus alpinae (*see* Cisco, longjaw)
artedii (*see* Herring, lake; Tullibee)
clupeaformis (*see* Whitefish, lake)
hoyi (*see* Bloater)
nasus (*see* Whitefish, broad)
reighardi (*see* Cisco, shortnose)
zenithicus (*see* Cisco, shortjaw)

Cornea (*see* Eye)

Cornick, John Walter
J 26(1): 1 (*Gaffkya homari* in lobster)
(9): 2503 (effects of temperature on gaffkemia)

Corrections
J 26(8): 2263 (to recent articles in this Journal)

Corticosterone derivatives (*see* Cortisol; Hormones; Steroids)

Cortisol (*see also* Hormones; Steroids)
J 26(7): 1789 (injection effects on secretion rate of gonadectomized female sockeye salmon)
S 1308 (binding by fish plasma proteins)
1310, 1338 (changes in dynamics of, re sockeye salmon sexual maturation)
1337 (adrenalectomy effect on American eel plasma cortisol, etc.)

Corynebacterium
J 26(10): 2659 (sp. ingested by oligochaetes in Toronto harbour sediments)
(10): 2760 (in culturing algal feed for rearing bivalve larvae)

Coryphaenoides acrolepis (*see* Rattail, rough-scale)
pectoralis (*see* Rattail, pointed)

Coryphopterus nicholsi (*see* Goby, bluespot)

Cottus bairdi (*see* Sculpin, mottled)
ricei (*see* Sculpin, spoonhead)

Couesius plumbeus (*see* Chub, lake)

Courtship (*see* Reproduction)

Crab, Dungeness (*Cancer magister*)
J 26(2): 389 (culturing larvae)
B 169 : 157 (predator on Pac. oyster, B.C.)

Crab, graceful (*Cancer gracilis*)
B 169 : 157 (predator on Pac. oyster, B.C.)

Crab, hermit (*Pagurus*)
J 26(7): 1899 (in W Canadian Arctic)

Crab, Jonah (*Cancer borealis*)
T 122 (catches in experimental otter trawling, NW Atl., 1968)

Crab, king (*Paralithodes camtschatica*)
J 26(10): 2737 (delayed mating effects on reproduction)
S 1264 (desmosterol & 6 other sterols in)

Crab, queen (*Chionoecetes opilio*) (spider crab)
J 26(7): 1899 (in W Canadian Arctic)
T 102 (underwater observations (queen crab) from cubmarine)
S 1264 (desmosterol & 3 other sterols in)
A 132 (FRB research on)
136 (underwater observations from cubmarine)
138 (distribution, biology, fishery, processing, etc.)

Crab, red (*Geryon quinquedens*)
T 122 (catches in NW Atl. experimental otter trawling, 1968)

Crab, rock (Atlantic) (*Cancer irroratus*)
T 122 (catches in experimental otter trawling, NW Atl., 1968)

Crab, rock (Pacific) (*Cancer productus*)
B 169 : 157 (predator on Pac. oyster, B.C.)

Crab, spider (*see* Crab, queen)

Crab, toad (*Hyas coarctatus*)
J 26(7): 1899 (W Canadian Arctic)

Craigie, James Smith
J 26(10): 2703 (sublittoral flora of Halifax Co., N.S.)
(11): 2959 (*Monochrysis lutheri* salinity-induced changes)

Cranium (*see* Osteology)

Crassostrea gigas (*see* Oyster, Pacific)
virginica (*see* Oyster, Atlantic)

Crayfish
J 25(8): 1651 (plasma protein-bound inorganic iodide of *Cambarus*)
A 135 (endocrine levels effect on *Orconectes virilis* moulting photoperiod)

Creatine
J 26(10): 2621 (re critical freezing zone of Atl. cod muscle)

Crecy Lake, N.B.
J 26(12): 3101 (environment & biota changes after fertilization)

Cristispira (spirochaete)
B 169 : 21 (associated with Pac. oyster crystalline style)

Crossman, Edwin John
J 26(1): 175 (pike & muskellunge identification)

Crustaceans (*see also* subclassifications, *also* certain species names)
J 26(1): 55 (in Wash. coast benthic infauna standing crop)
(2): 361; (5): 1321; (9): 2283 (5 species of Haustoriidae)
(5): 1273 (in Atl. cod & haddock feed)
(8): 2135 (composition & horizontal distribution, L. Ontario)

Cryoprotective agents (*see* Refrigeration)

Ctenophora (*see Berõe*)

Cubmarine (*see* Submarine)

Culaea inconstans (*see* Stickleback, brook)

Culley, Dudley D., Jr.
J 26(9): 2395 (resistance patterns in mosquitofish)

Culture (invertebrates) (*see also* Feed)
J 26(1): 150 (calanoid copepods in synthetic sea water)
(2): 299 (bacteriovorous Protozoa)
(3): 389 (Dungeness crab larvae)
(4): 741 (*Schistocephalus solidus* cestode)
(4): 935 (*Phocanema decipiens* nematode)
(5): 1133 (experimental nutrient enrichment of sea water for phytoplankton)
(5): 1347 (chemical factors affecting calanoid copepod)
(5): 1385 (*Gaffkya homari*)
(6): 1605 (*Cyclops bicuspidatus thomasi*)
(8): 2250 (*Ligula intestinalis* cestode in laboratory)
(10): 2760 (bacterial flora of algal feeds for Atl. clam & oyster larvae)
B 169 : 48, 57, 65 (Pac. oyster, B.C.)
T 120 (tank, in Bedford Basin water, N.S.)
S 1285 (axenic, of *Hexamita inflata* protozoan from Atl. oyster)

Culture (vertebrates) (*see also* Feed)
J 26(2): 229 (natural vs. artificial stream rearing of sockeye salmon fry)
(2): 461 (factors affecting rainbow trout ovary cells in vitro)
(5): 1379 (mouse fibroblast cells for detecting water pollution)
T 107 (sablefish, in tanks)
120 (tank, of fish in Bedford Basin water, N.S.)

Cunner (*Tautogolabrus adspersus*)
J 26(3): 597(F) (retinal structure re activity, etc.)
(3): 701 (susceptibility to abnormally low estuarial salinity)

Currents, marine (*see also* Oceanography)
T 99 (over sill of Saanich Inlet, B.C.)
115 (dye-tracing of, Margaree & Cheticamp R. estuaries, N.S.)
136 (re swordfish spawning in W Atl.)

Currents, reaction to
J 26(1): 21 (young smallmouth bass re shade)
(1): 33 (lakeward migrating young rainbow trout)
(2): 279 (benthic invertebrates upstream river movements)
(6): 1429 (re stream fish ecology)
(8): 2227 (simple tank for simulating rapids environment)

Curtis, Mark Andrews
J 26(12): 3279 (*Scoloplos acutus* synonymy with *S. armiger*)

Cusk (*Brosme brosme*)
J 26(2): 421 (cranial osteology re other Gadidae genera)

Cusk-eel (a deepsea) (*Parabassogagus grandis*)
J 26(6): 1680 (new range extension; morphometry)

Cuspidaria parapodema (septibranchid bivalve)
J 26(8): 2230 (new NW Pac. species)

Cuthbert, Robert Major
S 1309 (raw salmon color sorting)

Cyanaea capillata (a scyphomedusan)
J 26(6): 1535 (Ogac L., Baffin Is.)
(7): 1743 (experiments re feeding habits)

Cyclohexanetetrol
J 26(11): 2959 (salinity-induced changes of content in *Monochrysis lutheri* flagellate)

Cyclops bicuspidatus thomasi (a copepod)
J 26(6): 1605 (predation on zooplankton standing stocks)
(8): 2135 (horizontal distribution in L. Ontario)
(10): 2543 (seasonal abundance & vertical distribution, Parry Sound, Ont.)

Cyclops vernalis (a copepod)
J 26(10): 2543 (Parry Sound, Ont.)

Cyclopterus lumpus (*see* Lumpfish)

Cyclothone microdon (*see* Anglemouth, veiled)

Cymatogaster aggregata (*see* Perch, shiner)

Cyprinodon variegatus (*see* Minnow, sheepshead)

Cyprinus carpio (*see* Carp)

Cysteine
S 1314 (reaction with malonaldehyde)

Cystidicola (nematodes)
J 26(4): 849 (genus revision, from fish swim bladder)
S 1267 (taxonomy of Japanese species in *Oncorhynchus* salmons)
1299 (parasites of Pac. salmon's swim bladder)

Cystophora cristata (*see* Seal, hooded)

Cysts (*see* Disease)

Cytology (*see also* Chromosomes; Histology)
J 26(1): 111 (anemic coho salmon erythrocytes)
(2): 433 (blood cells of 3 estuarine cyprinodontiform fishes)
(3): 461 (rainbow trout ovary cells cultured in vitro)
(4): 845 (*Anenterotrema* trematode spp. parenchymal cells, re feeding mode)
(4): 965 (*Acanthosentis cameroni* acanthocephalan)
(4): 975 (*Bothrimonas* cestodes)
(4): 1075 (haematozoan protozoan parasitization of marine N.B. & New England fishes blood)
(5): 1147 (adult sockeye salmon pituitary after gonadectomy)
(7): 1837 (immunohistochemical localization of ACTH & prolactin in sockeye salmon pituitary)
(7): 1847 (brook trout aortic catheterization effects on blood)
(7): 1943 (winter flounder oocyte maturation duration)
(8): 2247 (infectious pancreatic necrosis virus in trouts pancreatic tissue)
(11): 2785 (effects of copper sulphate poisoning on winter flounder)
(11): 2881 (largemouth & smallmouth buffalofishes hematology)
(11): 2975 (interrenal tissue of normal vs. gonadectomized sockeye salmon)
S 1270 (amylopectin accumulation in cytoplasm of *Clostridium botulinum*)
1297 (enzyme degradation of hatching chum salmon egg capsule)

D

Dabrowski, Teofil
J 26(11): 2969 (chemical composition of shrimp flesh & nutritive value)

Dace, blacknose (*Rhinichthys atratulus*)
J 26(11): 3049 (5 lactate dehydrogenase isoenzymes in tissues, & in tissues of hybrid with longnose dace)

Dace, finescale (*Chrosomus neogaeus*)
J 26(6): 1439 (distribution in Canadian Missouri R. headwaters)

Dace, longnose (*Rhinichthys cataractae*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(11): 3049 (5 lactate dehydrogenase isoenzymes in tissues, & in tissues of hybrid with blacknose dace)

Dace, northern pearl (*Semotilus margarita nachtriebi*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Dace, northern redbelly (*Chrosomus eos*)
J 26(2): 325 (S Alta. distribution)
(3): 709 (first P.E.I. record)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Dambergs, Nikolajs
J 26(7): 1919 (isopropanol–water mixtures for fish protein concentrate from Atl. herring)
(7): 1923 (isopropanol–water azeotrope as fish protein concentrate solvent)

Danio malabaricus (*see* Danios, giant)

Danios, giant (*Danio malabaricus*) (tropical cyprinid)
J 26(8): 2250 (laboratory host for cestode culture)

Daphnia (Cladocera)
J 26(8): 2135 (*D. retrocurva* & *D. galeata mendotae* horizontal distribution in L. Ontario)

Darter, Iowa (*Etheostoma exile*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Dartmoor, England
J 26(8): 2165 (brown trout seasonal activity & feeding pattern)

Dartmouth Marine Ecology Laboratory, N.S.
A 134 (function)

Das, Bejoy Sanker
J 26(11): 3055 (tetrachloro-*o*-benzoquinone toxic to young salmon)

Das, Naresh
T 88 (larval herring spawning, distribution, survival, & growth)

Dasycottus setiger (*see* Sculpin, spinyhead)

Davenport, Douglas
T 113 (*G. B. Reed* groundfish cruise 69-1)
132 (*G. B. Reed* groundfish cruise 69-2)

Davey, Kenneth George
J 26(4): 935 (feeding in *Phocanema*)

Davis, Charles Carroll
J 26(9): 2459 (L. Erie zooplankton)

DDT (*see* Insecticides; Pesticides)

Decapoda (*see also* classifications; *also* common names)
J 26(7): 1899 (of Beaufort Sea & E to Cambridge Bay)
(8): 2219 (in feed of juvenile Pac. salmons)
S 1311 (distribution of in NW Atl.)

Decapterus macarellus (*see* Scad, mackerel)

Dechtiar, Alex O.
J 26(4): 865 (2 new trematodes from catostomids)

Defense mechanisms
J 26(1): 1 (lobster, against gaffkemia infection)
(1): 47 (Atl. salmon, against DDT insecticide toxicity)
(1): 115 (coho salmon, against bacterial endotoxins)

Deforestation
J 26(2): 399 (effects on stream temperature)

Dehydration (*see also* Desiccation)
J 26(12): 3271 (quality evaluation of freeze-dried vs. frozen Atl. cod steaks)
B 151(F) (freshwater fish products)

Dehydrogenases (*see* Enzymes)

Deleu, Siegfried Desideer
J 26(1): 171 (Malpeque Bay, P.E.I., physiographic changes 1845–1955 re oyster production)

Delphinapterus leucas (*see* Whale, white)

Delphinus delphis (*see* Dolphin, Pacific common)

DeLury population estimator
J 26(2): 339 (applicability robustness)

Density
J 26(8): 2077 (of Atl. & Pac. herring components, re buoyancy)
(8): 2093 (of Atl. salmon parr & smolt components, re buoyancy)
T 120 (Bedford Basin waters, N.S.)

Deoxyribonucleic acid (DNA) (*see* Acids, nucleic; Nucleotides)

Dermasterias imbricata (*see* Starfish, leather)

Dermatomya canadensis (*see Poromya canadensis*)

Desiccation (*see also* Dehydration)
J 26(9): 2283 (tolerance of 5 haustoriid amphipod species)

Desmosterol (*see* Sterols)

Detector, tag (*see* Tagging)

Detritus (*see* Matter, particulate; Sediments)

Development (*see also* Growth; Life history; Maturation; Metamorphosis)
J 26(6): 1485 (zooplankton, Ogac L., Baffin Is.)
T 100 (flathead sole embryonic)
105 (B.C. commercial groundfishes)

DeWilde, Mary Anne
J 26(7): 1847 (aortic catheterization re trout)

Dexamethasone (*see* Steroids)

Diamesinae
B 170 (descriptions, morphology, taxonomy, distribution, etc. of 5 species)
T 124 (classification of Nearctic)

Diaphus dumerili and *D. termophilus* (lanternfishes)
J 26(10): 2691 (recent records off N.S.)

Diaptomus (copepods)
J 26(8): 2135 (*D. minutus, D. oregonensis,* & *D. sicilis* horizontal distribution in L. Ontario)
(10): 2543 (*D. ashlandi, D. minutus, D. oregonensis,* & *D. sicilis* vertical distribution & seasonal abundance, Parry Sound, Ont.)

Diel habits (*see also* Behaviour; Light, reactions to)
J 26(1): 33 (lakeward migrating young rainbow trout)

(1): 63 (coho salmon fry activity & aggression cycles)
(2): 463 (light intensity periodicity in plankton photosynthesis)
(12): 3266 (4 fish species, Heming L., Man.

Dieldrin (*see* Insecticides)

Diet (*see* Feed; Feedstuff)

Digenea (*see also* Trematoda)
J 26(9): 2319 (list of species found in B.C. marine fishes)

Digestion (*see also* Feed)
J 26(7): 1801 (of pellet diets by rainbow trout)
B 169 : 18 (system of Pac. oyster)
T [illegible] (digestibility of Atl. herring meals)

Dimorphism
J 26(12): 3262 (sexual, in Pac. spiny lumpsucker)
S 1315 (sexual, in *Polinices lewisi* drill)

Dingle, John Reginald
S 1344 (gaffkemia in lobsters)
1349 (isolation of tropomyosin)

Dinoflagellata (*see Gonyaulax*)

Diphyllobothrium (cestodes)
J 26(4): 717 (*D. pacificum* in sea lions & man, Peru)
(4): 871 (transmission to lake trout)
(4): 947 (histology of *D. elegans, D. hians,* & new species *D. cameroni*)
(9): 2319 (in B.C. marine fishes)

Diplocotyle (*see Bothrimonas*)

Diptera (*see also* Insects, aquatic)
J 26(5): 1157 (feed, habits, ecology, in a small Que. stream)
B 171 (description, morphology, taxonomy distribution, etc. of N American, including 33 new species)

Discard of fish at sea
J 26(5): 1222 (American plaice)

Discoloration (*see also* Pigments)
CVG 43 (of sockeye & pink salmon during chilling on vessel)

Discriminant analysis
T 112 (FORTRAN 1130, computer program for)

Disease (*see also* Cytology; Gaffkemia; Immunology; Histology; Parasites; Pathology; Virus)
J 26(3): 629 (bacteriophages re trout furunculosis)
(6): 1459; (8): 2247; (9) 2511; (12): 3259 (infectious pancreatic necrosis virus in trouts & Atl. salmon)
(8): 2213 (microsporidial infection cysts of English sole)
(9): 2311 (disinfectants against *Aeromonas liquefaciens* in trout)
(9): 2535 (bacterial of feral vs. hatchery Atl. salmon kidney)
(12): 3242 (fibrous & cystic lesions in ovaries of aged Atl. cod)
B 169 : 164 (in Pac. oyster culture, B.C.)
S 1266 (Refsum's, in man)
1285 (*Hexamita inflata* protozoan re Atl. oyster)

Disinfectants
J 26(9): 2311 (re trout eggs transmission of *Aeromonas liquefaciens*)
B 169 : 147 (re Pac. oyster culture and handling)

Dispersal
J 26(7): 1867 (behaviour of young wild vs. hatchery-reared Atl. salmon in streams)

Distribution (biological) (*see also* Indicator species; Marking; Migration; Tagging)
J 26(2): 221 (triclad tubellarians in E Ont.)
(2): 325 (southern Alta. fishes)
(2): 361 (areal & vertical, of 3 sand-burrowing amphipod species)
(4): 909 (*Pomphorhynchus* acanthocephalan parasite of Atl. salmon, & of intermediate hosts)
(4): 947 (helminth parasites in pinnipeds)
(4): 1013 (*Caligus elongatus* parasitic copepod)
(5): 1121 (oyster drill, Canadian Atl. coast)
(5): 1157 (linear, of aquatic insects in a small Que. stream)
(5): 1390 (of 4 insular fish species, Sable Is., N.S.)
(6): 1439 (fishes of Missouri R. drainage in Canada)
(6): 1485 (vertical, of zooplankton, Ogac L., Baffin Is.)
(6): 1689 (grubby in Nfld. waters)
(7): 1699 (brook trout: native or introduced)
(7): 1727 (Wash. & S B.C. Ophiuroidea)
(8): 2135 (horizontal of L. Ontario crustacean plankton)
(9): 2431 (brook stickleback, Canada & USA)
(10): 2543 (vertical, of various planktonic copepods, Parry Sound, Ont.)
(10): 2581 (bottom corer for sampling vertical, of sedimentary benthos)
(10): 2691 (35 mesopelagic & other fishes, Gulf of St. Lawrence & N.S. banks)
(10): 2703 (vertical, of seaweeds, Halifax Co., N.S.)
(11): 2987 (*Salmincola* parasitic copepods)
B 168 : 18 (of temporarily toxic shellfishes in B.C.)

170 (N American Chironomidae, including 33 new species)
CJG 16 (Nfld. herring catches, 1967–68)
T 88 (Atl. herring larvae re Bay of Fundy hydrography)
105 (depth, of B.C. commercial groundfish)
136 (& origin, of W Atl. larval swordfish)
S 1268 (Que. stoneflies)
1302 (open N Pac., of chum salmon)
1311 (decapod crustaceans in NW Atl.)
A 138 (queen crab)

DNA (deoxyribonucleic acid) (*see* Acids, nucleic; Nucleotides)

Dockrill, April
J 26(1): 1 (*Gaffkya homari* in lobster)

Dogfish, spiny (Atlantic) (*Squalus acanthias*)
J 26(4): 805 (parasites, Nfld.)
T 103 (in experimental Atl. otter-trawling, 1967)
A 124 (use for fish protein concentrate)

Dogfish, spiny (Pacific) (*Squalus acanthias*)
J 26(8): 1985 (stock & yield forecast, N Pac. Ocean)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 117, 131 (B.C. commercial trawl landings, 1968)

Dollfus, Robert Philippe Ferdinand
J 26(4): 1037(F) (*Tetrarhynchus* cestodes)

Dolly Varden (*Salvelinus malma*)
J 26(2): 325 (S Alta. distribution)
(9): 2319 (parasites, B.C.)

Dolphin
B 171 : 15 (*Stenella euphrosyne* (?), B.C.)

Dolphin, northern right-whale (*Lissodelphis borealis*)
B 171 : 17 (presumable presence in B.C. waters)

Dolphin, Pacific or Atlantic, common (*Delphinus delphis*)
B 171 : 17 (single B.C. record)
T 103 (herd of 50 sighted during experimental otter trawling off NW Atl. coast)

Dolphin, Pacific striped (*Lagenorhynchus obliquidens*)
B 171 : 17 (description & records, of B.C.)

Dolphin, Risso's (*Grampus griseus*) (gray grampus)
B 171 : 23 (single B.C. record, & sightings in NE Pac. Ocean)

Dolphins
B 171 (killer whale, false killer whale, & Pac. pilot whale are dolphins)

Donaldson, Edward Mossop
J 26(7): 1789 (cortisol: effect of estrogen)
S 1292 (salmon pituitary gonadotropin in goldfish)
1310 (sockeye cortisol dynamics)
1336 (hormones & spermiation in goldfish)
1337 (adrenalectomy of the eel)
1338 (cortisol dynamics of sockeye)

Dorfman, Donald
J 26(9): 2493 (brook trout growth)

Douglas, Robert John
J 26(3): 629 (*Aeromonas salmonicida* phages)

Dragonfish, boa (*Stomias boa ferox*)
J 26(10): 2691 (new Canadian Atl. records; diurnal depth distribution)

Dragovich, Alexander
J 26(6): 1676 (*Lolliguncula brevis* measurements)

Dressing (*see* Gutting; Heading)

Driftfish, silver (*Psenes maculatus*)
J 26(10): 2698 (first Canadian record: off N.S.)

Drill, clam (*see* Clam drill)

Drill, oyster (*see* Oyster drill)

Drinnan, Roy Ellis
S 1285 (*Hexamita inflata* axenic cultivation from *Crassostrea virginica*)

Drozdowski, Bronislaw
S 1350 (production of fish protein concentrate from herring)

Drum (*see* Sheepshead)

Ducharme, Louis Joseph Andre
J 26(6): 1661 (Atl. salmon spawning trips)

Duedall, Iver W.
S 1273 (molal volumes of salts in sea water)
1274 (mercury dispenser)
1275 (nonwetting surface on glass)

Dugesia lugubris (a triclad turbellarian)
J 26(2): 221 (European immigrant into St. Lawrence R.)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Dunaliella tertiolecta (a phytoplankter)
J 26(6): 1625 (chlorophylls extraction procedure)

Dunn, Jean Richard
J 26(11): 3094 (black rockfish in central N Pac.)

Dunn, Rex Stewart
J 26(7): 1943 (anatomy of winter flounder ovary)

Durkin, Joseph Terrance
J 26(11): 3083 (detecting device for magnetized wire tags in migrating salmon)

Dyer, William John
J 26(6): 1597 (swordfish muscle nucleotide degradation)
(8): 2027 (Nfld. capelin composition)
(10): 2621 (cod muscle changes during freezing)
S 1290 (frozen fish storage life)

Dyes (*see* Pigments)

E

Eagle, Rodney J.
J 26(6): 1680 (first records of *Parabassogigas grandis*)

Eales, John Geoffrey
J 26(7): 1927 (silvering in freshwater fishes)
(8): 2093 (Atl. salmon buoyancy)

Eastman, Joseph Thornton
J 26(9): 2425 (arterial changes in carp)

Eaton, Catherine Anne
S 1286 (occurrence of squalene in fish)

Ebel, Wesley James
J 26(7): 1956 (tank to simulate reservoir conditions)
(11): 3083 (detecting device for magnetized wire tags in migrating salmon)

Ecdysis (*see* Moulting)

Echinarachnius parma (*see* Sand dollar)

Echinoderms (*see also* subclassifications; *also* certain species names)
J 26(1): 55 (in Wash. coast benthic infauna standing crop)
(1): 145 (zinc content)
(5): 1273 (in Atl. cod & haddock feed)
(7): 1727 (synopsis & key to Wash. & S B.C. Ophiuroidea)

Ecology (*see also* aspects of)
J 26(2): 361; (5): 1321 (comparative, of 5 Haustoriidae amphipod species)
(5): 1157 (aquatic insects in small Que. stream)
(6): 1415 (community concept in marine zoology)
(6): 1429 (distinctive aspects of stream fishes)
(6): 1485 (production, of zooplankton in Ogac L., Baffin Is.)
(8): 2211 (re yellowtail rockfish feed in submarine Astoria Canyon)
(11): 2843 (interpopulation dynamics model in marine)
B 168 : 14 (causative organism & toxicity in B.C. shellfishes)
S 1332 (implications re young coho salmon stream diet)
1334 (re limitations on salmonid stream populations production)
A 134 (function of Dartmouth Marine Ecology Laboratory, N.S.)

Economics (*see also* Fisheries; Management)
A 125 (fish protein concentrate manufacture)

Edelstein, Tikvah
J 26(10): 2703 (sublittoral flora of Halifax Co, N.S.)

Edington, John Malcolm
J 26(2): 399 (stream temperature)

Eel, American (*Anguilla rostrata*)
J 26(3): 639 (corpuscles of Stannius re renal physiology)
(3): 701 (mass mortality in abnormally low estuarial salinity)
B 151(F) (smoking and canning)
S 1337 (adrenalectomy effect on plasma cortisol)
1343 (fishermen's reports on freshwater & marine migrations)

Eel, Atlantic snipe (*Nemichthys scolopaceus*)
J 26(10): 2697 (recent catches off N.S.)

Eel, duckbill oceanic (*Nessorhamphus ingolfianus*)
J 26(10): 2691 (recent record off N.S.)

Eel, moray (*Gymnothorax javanicus*)
J 26(8): 2208 (liver & flesh ciguatoxin activity re anticholinesterase action)

Eelgrass (*Zostera marina*)
B 169 : 98 (re B.C. oyster culture)

Eelpout, arctic (*Lycodes reticulatus*)
J 26(3): 597(F) (retinal structure re activity, etc.)
(6): 1407 (*Tanypleurus alcicornis* copepod parasitic on gills)

Eelpout, bigfin (*Aprodon cortezianus*)
J 26(9): 2319 (parasites, B.C.)

Eelpout, blackbelly (*Lycodopsis pacifica*)
J 26(9): 2403 (biology, outer Burrard Inlet, B.C.)

Eelpout, Esmark's (*Lycodes esmarki*)
J 26(10): 2698 (off La Have Bank)

Eelpout, Laval's (*Lycodes lavalaei*) (*see also* Eelpout sp.?)
J 26(3): 597(F) (retinal structure re activity, etc.)

Eelpout, polar (*Lycodes turneri*)
J 26(3): 597(F) (retinal structure re activity, etc.)

Eelpout sp.? (*Lycodes terra-novae?*) (*see also* Eelpout, Laval's)
J 26(2): 311 (copepod parasite on fins)
(3): 597 (F)(retinal structure re activity, etc.)

Eelpout, Vahl's (*Lycodes vahlii*)
J 26(3): 597 (F) (retinal structure re activity, etc.)

Eggs; Ova (*see also* Embryos; Emergence; Fecundity)
J 26(4): 865 (*Pellucidhaptor* trematode)
(4): 975 (*Bothrimonus* cestode)
(7): 1943 (winter flounder oocyte maturation time)
(9): 2311 (disinfection of trout, re *Aeromonas liquefaciens*)
T 100 (development of flathead sole)
105 (B.C. commercial groundfishes)
111 (& milt of pink & sockeye salmon re spawn collection)
116 (development & numbers, *Clymenella torquata* polychaete)
S 1297 (enzymic degradation of capsule during hatching of salmon & trout)
1322 (pyruvate & glyoxalate metabolism by Atl. salmon)
1342 (aminotransferases in Atl. fishes)

Eisan, Joanne Sylvia
S 1322 (salmon eggs)
1342 (fish aminotransferases)

Eldjarn, Lorentz
S 1266 (LDD and DDD diastereoisomers of phytanic acid)

Eldridge, Peter John
J 26(7): 1955 (flag rockfish range extension)

Electroencephalograms
J 26(8): 2111, 2123 (olfactory bulbar, of chinook & coho salmon re discrimination & responses to natural waters)

Electrofishing
A 123 : 355 (in Nfld. salmon research)

Electrona arctica (*see* Lanternfish, bigeye)

Electrophoresis; Electropherograms
J 26(8): 2093 (lobster blood serum protein re moulting & reproduction)
(9): 2351 (Pac. halibut blood serum transferrins)
(10): 2633 (sablefish muscle protein phenotypes)
(11): 2969 (free & bound amino acids in an Atl. shrimp)
(11): 3049 (lactate dehydrogenase isoenzymes from dace)
(12): 3268 (transferrin phenotypes from Pac. hake serum)

Embryos
J 26(9): 2339 (number & size re age & size of female shiner perch)
T 100 (flathead sole development)

Emergence
S 1333 (adaptations of newly hatched sockeye salmon to stream conditions)

Endocrinology (*see* Hormones; Steroids)

Endotoxins
J 26(1): 115 (coho salmon & rainbow trout resistance to bacterial)

Energy, radiant (*see also* Light, reactions to)
S 1295 (re indices of oceanic primary & secondary production)
A 130 (for fish muscle & products preservation)

Energy, tidal (*see* Tides)

Engraulis mordax (*see* Anchovy, northern)

Ennis, Gerald Peter
J 26(6): 1689 (*Myoxocephalus aeneus* in Nfld. waters)

Entodiscus borealis (*see* Ciliata)

Environment (*see also* Behaviour; Ecology; *also* factors affecting environment)
J 26(6): 1429 (classifications re stream fishes ecology)
(10): 2715 (effects of simulated long-term fluctuations of, on maximum sustained yield)
(12): 3101 (changes in Crecy L., N.B., after fertilization)

Enzymes
J 26(1): 15 (blood serum lactate dehydrogenase isoenzymes variants in sockeye salmon populations)
(6): 1577 (re free fatty acid derivation in Atl. herring commercial oils)
(7): 1857 (lipolytic, in rainbow trout muscle)

(8): 2193 (acetylcholinesterase activity of rainbow trout larvae subjected to insecticide)
(8): 2208 (anticholinesterase action of toxin from moray eel)
(9): 2299 (catalase)
(9): 2517 (glyceraldehyde-3-phosphate dehydrogenase: temperature effect on activity of)
(9): 2532 (polymorphic serum esterases suited for population analysis of white bream & ruff)
(11): 3049 (lactate dehydrogenase isoenzymes in dace tissues)
(12): 3175 (alpha-glycerophosphate dehydrogenase activity as new test for iced-storage age of fresh gutted fish)
(12): 3209 (effect of feeding and DDT on activity of glucose 6-phosphate dehydrogenase in fish liver)
S 1297 (degrading salmon & trout egg capsule preparatory to hatching)
1329 (of scallop gonadal tissue converting C-21 to C-19 steroid)
1342 (alanine & aspartate aminotransferases in Atl. fishes eggs & sperm)

Eopsetta jordani (*see* Sole, petrale)

Ephemeroptera
J 26(5): 1157 (feed, habits, ecology, in small Que. stream)
(12): 3101 (list of Crecy L., N.B.)
T 130 : 224 (of Nfld. streams)

Epibenthos (*see also* Benthos)
J 26(8): 2003 (algal production & community respiration in Marion L., B.C.)

Epischura lacustris (a copepod)
J 26(10): 2543 (Parry Sound, Ont.)

Eptatretus deani (*see* Hagfish, black)

Equipment (*see* Apparatus; Gear)

Ergasilus arthrosis (parasitic copepod)
J 26(4): 997 (new species; *Ergasilus* genus taxonomy)

Erie, Lake (*see also* Great Lakes)
J 26(7): 1877 (walleye maturity & fecundity)
(9): 2459 (zooplankton seasonal distribution, constitution, & abundance)

Errata (*see* corrections)

Erythrocytes (*see* blood)

Escapement (*see also* Fisheries; Spawning)
J 26(3): 655 (Bristol Bay sockeye salmon, re spawning potential estimation method)
(10): 2715 (re catch, stock recruitment, reproductive curve systems, & environmental fluctuations)

Eschrichtius gibbosus (*see* Whale, gray)

Esox americanus (*see* Pickerel, redfin)
lucius (*see* Pike, northern)
masquinongy (*see* Maskinonge)

Estrogens (*see* Hormones)

Estuary (*see also* name of river)
J 26(3): 701 (bottom fauna mass mortality due to abnormally low salinity, P.E.I.)

Etheostoma exile (*see* Darter, Iowa)

Ethylenediaminetetraacetic acid (EDTA) and salts
J 26(10): 2651 (re spoilage repression of petrale sole and ocean perch fillets)

Eualus spp. (hippolytid shrimps)
J 26(7): 1899 (of W Canadian Arctic)

Eucalia inconstans (*see* Stickleback, brook)

Euchaeta japonica (*see* Calanoida)

Eulachon (*Thaleichthys pacificus*)
J 26(9): 2319 (parasites, B.C.)
S 1286 (squalene hydrocarbon content)

Eumesogrammus praecisus (*see* Snakeblenny, fourline)

Eumetopias jubatus (*see* Sea lion, Steller)

Eumicrotremus orbis (*see* Lumpsucker, Pacific spiny)

Euphausiids
J 26(6): 1631 (*Euphausia pacifica* vs. copepods in chum salmon selective feeding)
(8): 2211 (*Thysanoëssa spinifera* & *E. pacifica* as yellowtail rockfish feed)

Europe
T 134 (Atl. salmon stocks; parasite indicator species for distinguishing from Greenland and N American)

Eurytemora (*see also* Calanoida; Copepoda)
J 26(1): 150 (*E. affinis* culture in synthetic sea water)
(8): 2135 (*E. affinis* horizontal distribution in L. Ontario)
(10): 2543 (*E. affinis* in Parry Sound, Ont.)

Eutrophication (*see also* Limnology; Oceanography; Pollution)
J 26(12): 3101 (Crecy L., N.B.)
S 1341 (studies of inlet extension of Victoria harbour, B.C.)

Evasterias troschellii (*see* Starfish, mottled)

Evolution
J 26(12): 3183 (re red & black threespine sticklebacks)

Exercise (*see* Activity; Stress; Swimming)

Exploitation
J 26(1): 179 (computer programming for estimation of exploited populations)
(5): 1205 (effects on American plaice stock)

Exploration
J 26(8): 1985 (demersal fishes survey & methods, N Pac. Ocean)
T 103 (list of fishes, etc. taken in Atl. otter-trawl survey, 1967)
A 138 (for queen crab, Nfld., Que., N.S., N.B., P.E.I.)

Eye (*see also* Light, reactions to; Vision)
J 26(1): 143 (copepod parasite on Greenland shark cornea)
(2): 311 (copepod parasite on deepsea chimera cornea)
(3): 597(F) (retinal structure of 20 Atl. fishes re activity, etc.)
(4): 921 (copepod parasite of arrowtooth flounder)
(7): 1927 (purine source of silvery layer in walleye & pike)

F

Fagerlund, Ulf Henrik Mathias
J 26(7): 1789 (cortisol: effect of estrogen)
S 1310, 1338 (sockeye cortisol dynamics)
1340 (dexamethasone in sockeye)

Family, new
J 26(10): 2595 (Acrocirridae Polychaeta, formerly Cirratulidae)

Farmer, Gilbert John
J 26(11): 2807 (oxygen consumption of *Tilapia nilotica* re swimming speed & salinity)

Farrington, John William
J 26(9): 2517 (glyceraldehyde-3-phosphate re temperature effect)

Fat (*see* Acids, fatty; Condition; Lipids; Oils and fats; Phospholipids; Triglycerides)

Fatigue (*see* Activity; Stress)

Fatty acids (*see* Acids, fatty)

Fauna, aquatic (*see also* Benthos; Biomass; Lists; *also* types and names of)
T 130 (of many Nfld. streams)

Fauna, bottom (*see* Benthos; Fauna, aquatic)

Feces
J 26(6): 1459 (re detection of infectious pancreatic necrosis virus in brook trout)

Fecundity (*see also* Reproduction; Spawning)
J 26(2): 361; (5): 1321 (of 5 Haustoriidae amphipod species)
(2): 473 (mailed sculpin, Gulf of Maine)
(3): 655 (Bristol Bay sockeye salmon)
(5): 1289 (W L. Superior longnose sucker)
(6): 1585 (differences between 2 Nfld. populations of landlocked Atl. salmon)
(7): 1877 (E & W L. Erie walleyes)
(8): 1969 (& breeding of glass shrimp, Gulf of Maine)
(8): 2245 (*Mytilicola orientalis* parasitic copepod)
(9): 2339 (re age & size of shiner perch)
(11): 2795 (of roach & bleak in River Thames, England)
(12): 3133 (cod off SW Nfld.)
T 105 (B.C. commercial groundfishes)
116 (*Clymenella torquata* polychaete)

Feed; Feeding habits; Stomach contents (*see also* Culture; Feedstuff; Nutrition value; Predation)
J 26(1): 143 (Greenland sharks, N Baffin Is.)
(1): 175 (distinguishing northern pike & muskellunge remains in fish stomachs)
(2): 357 (adding canthaxanthin to young trouts & pink salmon feed to enhance flesh colour)
(2): 361 (of 3 Haustoriidae amphipod species)
(3): 557 (particulate & filter feeding by northern anchovy)
(3): 583; (5): 1273 (Atl. cod behaviour)
(4): 845 (special nutrition modes of *Anenterotrema* trematodes)
(4): 871 (lake trout re *Diphyllobothrium* transmission)
(4): 879 (Atl. argentine re trematode infestation)
(4): 935 (timing during *Phocanema decipiens* nematode moulting cycle)
(5): 1273 (comparison of Atl. cod & haddock)
(6): 1429 (habits re stream fishes ecology)
(6): 1585 (differences in 2 Nfld. populations of landlocked Atl. salmon)
(6): 1605 (*Cyclops bicuspidatus thomasi* predation including cannibalism)

(6): 1631 (young chum salmon growth on euphausiid vs. copepod feed)
(7): 1743 (experiments re some medusae & Chaetognatha habits)
(7): 1801 (rainbow trout digestive response to pellet diets)
(7): 1899 (Canadian E arctic decapod Crustacea)
(8): 1969 (glass shrimp)
(8): 2165 (brown trout re feed availability in a British stream)
(8): 2211 (ecology of yellowtail rockfish in submarine Astoria Canyon)
(8): 2219 (juvenile Pac. salmons in Chatham Sound, B.C.)
(9): 2363 (conversion efficiency of young sockeye salmon)
(9): 2403 (blackbelly eelpout, Burrard Inlet, B.C.)
(12): 3165 (winter, of zooplankton, Strait of Georgia, B.C.)
(12): 3237 (statistical analysis of ration re growth of European plaice)
(12): 3275 (brown & rainbow trout night feeding in experimental stream channel)
B 169 : 43 (Pac. oyster, B.C.)
T 105 (B.C. commercial groundfishes)
S 1300 (blood feeding of *Salvelinema* nematode on coho salmon swim bladder)
1305 (marine microorganisms biomass associated with young Pac. salmons & trout)
1317 (salmon off Nfld.)
1332 (ecological implications of, for young coho salmon in stream)
1334 (limitations re salmonid stream populations)
A 133 (food of cod)
138 (queen crab)

Feedstuff (*see also* Fishmeal)
CNS 28 (B.C. commercial fishes landings for animal feed)
CVG 42 (for chicks, from salmon & herring processing recovered solids)
T 107 (for rearing sablefish in tanks)
117, 131 (B.C. commercial trawl landings for animal feed, 1968)

Ferguson, Denzel Edward
J 26(9): 2395 (resistance patterns in mosquitofish)

Fernando, Constantine Herbert
J 26(4): 833 (yellow perch parasites)

Fertilization (*see also* Egg; Fertilizer; Reproduction; Semen)
J 26(5): 1400 (of steelhead trout with cryo-preserved sperm)

Fertilizer
J 26(5): 1133 (experimental nutrient enrichment of sea water re phytoplankton growth)
(12): 3101 (changes in environment & biota of Crecy L., N.B., after fertilization)

Fessler, James Laurence
J 26(11): 2823 (steelhead trout morphological & biochemical changes during parr–smolt change)

Fibres
A 129 (synthetic, characteristics of for fishing gear)

Fillets
J 26(1): 175 (identifying northern pike vs. maskinonge)
(10): 2651 (EDTA effect on spoilage characteristics of petrale sole & Pac. ocean perch)
(12): 3217 (bacteriology of Nfld. commercial, from cod & flounder frozen at sea & thawed in water)
B 151(F) (processing of freshwater fishes)
CHN 35 (blast freezing rates and weight loss, for haddock)
S 1290 (deterioration & storage life of frozen Atl. cod)

Filter
S 1345 (retention of marine particles by)

Fins (*see also* Marking; Tagging)
J 26(2): 311 (copepod parasitic on eelpout & wolffish)
(3): 633 (white sucker fin rays vs. scales, for aging)
(5): 1199 (sockeye & chum salmon pectoral fin rays for aging)
(5): 1263 (finclipping effect on young sockeye salmon survival)
(6): 1619 (effect of fluorescent pigment marking vs. finclipping on coho salmon fry survival)
(9): 2431 (geographical variation in brook stickleback spines)
(9): 2537 (Atl. mackerel: fin rays counts re N American populations)

Fish flour (*see* Fish protein concentrate)

Fish protein concentrate (Fish flour; FPC)
J 26(7): 1919, 1923 (isopropanol–water mixtures, including azeotrope, for fat extraction in Atl. herring)
S 1339 (fluoride determination method for, and data)
1350 (oil & lipids extraction from Atl. herring for)
A 124–127 (Halifax process; nutritive values; economics of production; fish resources & utilizations for)

Fishballs
B 151(F) (recipes & processing of freshwater fish)

Fisheries (*see also* Catches; Stocks; *also* names of commercial fishes, shellfishes, etc.)
J 26(2): 269 (NW Margaree R., N.B., salmon migration to commercial and angling)

(5): 1205 (exploitation effects on Magdalen shallows American plaice stock)
(8): 1985 (demersal, NE Pac. Ocean areas)
(8): 2027 (undeveloped, of Nfld. beach-spawning capelin)
(10): 2754 (sport: sex ratio of steelhead trout, Babine R., B.C.)
(12): 3133 (cod, off SW Nfld.)
B 169 : 174, 178, 189 (Pac. oyster in B.C.: leases, regulations, etc.)
171 : 50 (B.C. whales, 1905–67)
CJG 16 (investigations & groundfish landings, Nfld., 1968)
CNS 27 (age composition of 1965 B.C. commercial sockeye, chum, & pink salmon catches)
28 (Canadian & American trawl catches from grounds off B.C., 1954–65)
T 86 (Canadian cod & haddock, 1965)
108 (Canadian & American catches of rock sole, 1945–64)
117, 131 (catch & effort statistics, B.C. commercial trawl, 1968)
S 1283 (Nfld. herring, re its resource)
1284 (recent developments in Georges Bank scallop)
1316 (Scotian Shelf haddock)
1318 (W Nfld. cod)
A 122 (B.C. whaling industry)
131(F) (swordfish)
138 (queen crab, Atl. coast)

Fisheries Research Board of Canada (*see also* Publications and reports, Fisheries Research Board of Canada)
AR 1968 (Annual Report: Board members; Executive Committee members; officers; establishments & directors; Chairman's review: 1968 research programs; Board Act (in English and French))
R 1967/1968 (Biennial Review: Board members; organization; reviews of investigations by establishments, with lists of scientific staffs; list of 1967 and 1968 Board publications & reports)
MSP 12 (brochure describing St. Andrews Station for visiting aquatic scientists)
A 132 (what it does to help Atl. fishermen)
134 (work of Dartmouth Marine Ecology Laboratory)

Fishery, sport (*see* Angling; *also* names of species, e.g., salmon; trout)

Fishes, lists of
J 26(4): 1075 (marine, examined for haematozoan protozoan blood parasites, N.B. & New England)
(6): 1439 (in Canadian headwaters of Missouri R.)
(10): 2769 (recent records, Atl. coast of Canada)
T 103, 122 (taken during Atl. otter-trawl surveys, 1967 & 1968)
113, 132 (taken during research groundfish cruises, B.C., 1969)
117 (taken during B.C. commercial trawl fishery, 1968)
130 : 227 (Nfld. streams)
S 1279 (taken by two research trawlers fishing together)
1348 (rare fishes from Clyde sea area, W Scotland)

Fishing, exploratory (*see* Exploration)

Fishmeal
T 114 (chemical & nutritive characteristics of Canadian Atl. herring meals)
131 (B.C. trawl landings for conversion to)

Fitzgerald, Durell Nelson
J 26(5): 1273 (cod & haddock food)

Flagellata (*see also* Dinoflagellata)
J 26(11): 2959 (salinity-induced growth, pigments, & cyclohexanetetrol content of *Monochrysis lutheri*)

Flame ionization detector
S 1265 (re molecular breakdown & fundamental group responses for organic compounds)

Flatfishes (*see* Groundfish; *also* names of species)

Flatwater Pond, Nfld.
J 26(6): 1585 (landlocked Atl. salmon population characters)

Flavobacterium
J 26(10): 2659 (sp. ingested by oligochaetes in Toronto harbour sediments)
(10): 2760 (in culturing algal feed for rearing bivalve larvae)

Flavour (*see also* Quality of fishery products)
J 26(3): 704 (role of nucleotides in canned shrimp)
(6): 1597 (role of nucleotides in frozen swordfish steaks)
CVG 43 (effect of delay in chilling in refrigerated seawater on vessel, re canned sockeye & pink salmon)
T 101 (of experimentally canned ocean quahaug)
A 130 (compounds contributing to fish flesh)

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Fleming, Allister Melville
CJG 16 (1968 Nfld. groundfish landings)

Flesh (*see also* Browning of flesh; Fillets; Muscle; Protein; Quality of fishery products)
J 26(10): 2561 (meat weight in white whales)
B 169 : 120 (meat yield from Pac. oyster)
S 1309 (colour sorting of raw sockeye & coho salmon re subsequent colour of canned)

Flexiphora ophidii (monogenetic trematode)
J 26(4): 1063 (description)

Floatation
CVG 42 (solids recovery from salmon-canning & herring-pumping waste waters)

Flora, aquatic (*see also* Algal; Benthos; Biomass; Productivity, primary; Seaweeds; *also* types and names of)
J 26(12): 3101 (changes after several fertilizations of a lake)

Flounder, arrowtooth (*Atheresthes stomias*) (Pacific turbot)
J 26(4): 921 (*Phrixocephalus cincinnatus* copepod eye parasite biology)
(8): 1996 (stock & yield forecast, N Pac. Ocean)
CNS 28 (B.C. commercial landings for animal feed)
T 135 (length–weight relations)

Flounder, starry (*Platichthys stellatus*)
J 26(1): 191 (senistrality percentage increase from S to N B.C.)
(9): 2319 (parasites, B.C.)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 117, 131 (B.C. commercial trawl landings, 1968)
135 (length–weight relations)

Flounder, winter (*Pseudopleuronectes americanus*)
J 26(4): 975 (*Bothrimonus* cestode biology in)
(7): 1943 (ovary anatomy re oocyte maturation)
(11): 2785 (detailed tissues study re copper sulphate poisoning)
A 136 (underwater observation from submarine)

Flounder, witch (*Glyptocephalus cynoglossus*)
J 26(3): 597(F) (retinal structure re activity, etc.)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)
A 119 (ICNAF 1967 Canadian research report on)

Flounder, yellowtail (*Limanda ferruginea*)
J 26(3): 597(F) (retinal structure re activity etc.)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)
A 119 (ICNAF 1967 Canadian research report on)

Flour, fish (*see* Fish protein concentrate)

Flukes (*see* Trematoda)

Fluorescence
J 26(5): 1185 (ultraviolet-fluorescing substances in coho salmon belly skin)
(5): 1263 (of tetracycline absorbed by bone for marking salmon fry)
(5): 1368 (by muscle nucleotides of white sucker muscle)
(6): 1619 (of pigment for external marking of salmon fry)
(6): 1667 (of dyes re separation of invertebrates from sediments)

Fluorine compounds
S 1339 (fluoride determination in biological samples of fish protein concentrates)

Foley, Diane Mary
J 26(5): 1385 (lobster disease gaffkemia)
(5): 1392 (lobster hemolymph)

Folic acid
J 26(1): 111 (deficiency effect on coho salmon blood)

Food of animals (*see* Feed; Feedstuff)

Forecasting
J 26(8): 1985 (stock size & yield, NE Pac. Ocean demersal fishing)
(11): 2843 (Pac. sardine catches re predator & prey ecology)
B 168 : 33 (possible outbreaks of toxicity in shellfishes)
169 : 65 (spatfall of Pac. oyster, B.C.)

Forrester, Clifton Roger
J 26(1): 191 (starry flounder sinistrality)
CNS 28 (Canadian & U.S. trawl production 1954–65)
T 100 (flathead sole embryonic development)
105 (groundfish life-history information)
108 (studies on the rock sole)
131 (B.C. trawl fishery 1968)
135 (groundfish length–weight relation)
S 1319 (English sole tagging in B.C.)

Forsythe, Michael George
T 91 (Miramichi R., N.B., smolt run 1966)

Foulkes, Timothy James
T 125 (otter trawl performance)

Fowler, Scott Wellington
J 26(1): 145 (marine organisms zinc requirements)

FPC (fish protein concentrate) (*see* Fish protein concentrate)

Fragillaria sp. (a phytoplankter)
J 26(6): 1625 (chlorophylls extraction procedure)

Fraser, Doris Isabel (*see* Hiltz, Doris Isabel)

Fraser, James Henry
J 26(7): 1743 (medusae & Chaetognatha feeding)

Freeman, Harry Cleveland
S 1308 (plasma proteins of fish)

Freeman, Reino Samuel
J 26(4): 871 (*Diphyllobothrium* in trout)

Freese, Manfred
S 1269 (freshwater fish tissue properties)

Freeze-drying (*see* Dehydration)

Freezing (*see also* Refrigeration; Thawing)
J 26(10): 2621 (glycolytic & nucleotide changes in critical zone of prerigor Atl. cod muscle)
(10): 2727 (fatty acids reaction with Atl. cod muscle aged in ice)
(12): 3254 (Atl. salmon spermatozoa using an extender)
CHN 35 (blast-freezing rates & weight loss for haddock fillets & pieces)
T 93 (Atl. salmon sperm with extenders & protective agents)

Freshwater fish products
B 151(F) (processing & recipes)

Fromm, Paul Oliver
J 26(7): 1939 (rainbow trout uptake of dieldrin)

Fry (*see* names of adult fishes, e.g. Trout; Salmon)

Fry, Frederick Ernest Joseph
J 26(9): 2413 (survival of planted lake trout)

Fulton, John Douglas
T 110 (Strait of Georgia observations)

Fundulus heteroclitus (*see* Mummichog)
majalis (*see* Killifish, striped)
parvipinnis (*see* Killifish, Pacific)

Fundy, Bay of
J 26(9): 2477; (11): 2775 (tidal barriers effect on M_2 tide, re tidal power projects)
(11): 2887 (theory of tidal energy exploitation re)
T 88 (herring spawning & larval distribution, survival, & growth re hydrography)

Furunculosis
J 26(3): 629 (bacteriophages re *Aeromonas salmonicida*)
(9): 2311 (transmissivity similarity to *A. liquefaciens*)

G

Gadidae (*see also* names of individual species)
J 26(2): 421 (comparative cranial osteology)
(4): 1063 (speciation, as hosts of *Diclidophora* trematode on gills)

Gadus
J 26(2): 421 (cranial osteology re other Gadidae genera)

Gadus macrocephalus (*see* Cod, Pacific)
morhua (*see* Cod, Atlantic)

Gaffkemia (*see also Gaffkya*)
J 26(1): 1 (natural defences of lobster against)
(9): 2503 (temperature effect on lobster susceptibility)

Gaffkya homari (pathogenic bacteria) (*see also* Gaffkemia)
J 26(5): 1385 (characteristics; culture)
S 1344 (effects on lobster physiology)

Gambusia affinis (*see* Mosquitofish)

Gammarus (amphipods)
J 26(4): 909 (as intermediate hosts of parasitic acanthocephalan)
(4): 975 (*Bothrimonus* cestode biology in)

Gardella, Edward Stewart
J 26(8): 2173 (white bass orientation)

Gardner, George Robert
J 26(2): 433 (cyprinodontiform blood morphology)

Garside, Edward Thomas
J 26(2): 460 (blackspotted stickleback in Nfld.)
(5): 1390 (Sable Is. fishes)
(9): 2537 (Atl. mackerel meristic analyses)

Gasterosteus aculeatus (*see* Stickleback, threespine (freshwater))
wheatlandi (*see* Stickleback, blackspotted)

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Gastric secretion (*see* Digestion; Stomach)

Gastropoda (*see also* subclassifications and names of species)
J 26(12): 3101 (of Crecy L., N.B.)
A 133 (caloric content of 3 species)

Gear (*see also* Nets; Traps)
J 26(9): 2527 (various hooks for deepsea line fishing)
T 104 (B.C. scallop drags)
A 138 (for queen crab fishing)

Gee, John Henry
J 26(8): 2227 (simulating rapids environment)
(11): 3049 (longnose & blacknose dace & hybrid isozymes)

Geiger, Shirley Evelyn
CVG 41 (weight changes in Pac. coast fish stored at sea)
43, 44 (storage of Pac. salmon at sea)

Genera, new (*see also* Family, new; Species, new)
J 26(2): 311 (*Clavellomimus* parasitic copepod)
(4): 787 (*Saturnius, Bilacinia,* & *Unilacinia* hemiurid trematodes from Australian fishes)
(4): 1037(F) (*Mustelicola* tetrarhynchian cestode)
(11): 2987 (subgenera of *Salmincola* parasitic copepods)
S 1301 (*Praecidochondria* parasitic copepod)
1306 (*Shiinoa* parasitic copepod)

Genes; Genetics (*see also* Chromosomes; Heredity)
J 26(5): 1397 (distribution of frequencies in harp seal blood transferrins)
(9): 2351 (distribution of frequencies in Pac. halibut blood transferrins)
(9): 2532 (frequency data re populations analysis of white bream & ruff)
(10): 2633 (re E Pac. sablefish population parameters)
(12): 3183 (re red & black threespine sticklebacks)
S 1335 (possible genetic variations in salmons resulting from managed populations)
1354 (rostellar hooks development re Cyclophyllidea cestodes phylogenetics)

Genital system (*see* Eggs; Hormones; Ovary; Reproduction; Testes)

Geology (*see also* Geomorphology; Morphometry (physical); Physiography)
T 130 (surface, re Nfld. streams productivity)
S 1353 (Gulf of St. Lawrence region)

Geomorphology (*see also* Physiography)
T 98 (Little Codroy R. & estuary, Nfld.)
S 1353 (Gulf of St. Lawrence S region)

Georges Bank, off N.S.
T 86 (Canadian trawl catches of cod & haddock, 1965)
S 1284 (recent scallop fishery developments)

Georgia, Strait of, B.C.
J 26(12): 3165 (bacteria & other heterotrophs as winter zooplankton feed)
T 110 (biological oceanography investigations summary, 1965–68)

Georgian Bay, Lake Huron, Ont. (*see* Parry Sound)

Geryon quinquedens (*see* Crab, red)

Gilbertidia sigalutes (*see* Sculpin, soft)

Gillnet and Netting (*see* Nets)

Gill rakers (*see* Gills)

Gills
J 26(1): 165 (dimensions, re size of various fishes)
(2): 311 (copepod parasitic on Atl. wolffish)
(4): 833 (parasites on yellow perch)
(4): 1063 (*Diclidophora* trematodes on gadid fishes)
(6): 1680 (gill arch characters of *Parabassogigas grandis*)
(7): 1934 (gill-raker counts re differentiating *Coregonus artedii* from *C. zenithicus*)
(7): 1939 (uptake of pesticide by rainbow trout)
(9): 2283 (area re respiration of 5 haustoriid amphipod species)
(11): 2785 (copper sulphate toxicity effects on winter flounder)

Girella nigricans (*see* Opaleye)

Glass apparatus (*see also* Apparatus)
S 1275 (a silicone for producing nonwetting surface on)

Glass, Norman Ralph
J 26(10): 2643 (power function re fish respiratory metabolism)

Globicephala macrorhynchus (*see* whale, Pacific pilot)

Glossary
B 169 : 185 (re Pac. oyster & its culture)

Glugea hertwigi (*see* Sporozoa)

Glycerides (*see* Triglycerides; *also* Acids, fatty; Lipids; Oils and fats)

Glycogen
J 26(10): 2621 (glycolytic changes in critical freezing zone of Atl. cod muscle)

B 169 : 115 (re Pac. oyster condition)

Glycol
J 26(12): 3254 (advantage of propylene over ethylene as extender for freezing salmon sperm)

Glyoxalate
S 1322 (metabolism by Atl. salmon eggs)

Glyptocephalus cynoglossus (*see* Flounder, witch)
zachirus (*see* Sole, rex)

Goby, bluespot (*Coryphopterus nickolsi*)
J 26(9): 2319 (parasites, B.C.)

Godin, Gabriel
J 26(11): 2887 (tidal energy exploitation theory re Bay of Fundy)

Goldeye (*Hiodon alosoides*)
J 26(2): 325 (S Alta. distribution)
B 151(F) (smoking)

Goldfish (*Carassius auratus*)
J 26(7): 1927 (purine sources of skin silvering)
(10): 2651 (oxygen metabolism re body weight)
S 1292, 1336 (spermatogenesis & ovulation induction in hypophysectomized, by chinook salmon pituitary gonadotropin)

Goldsack, Douglas Eugene
S 1347 (amino acid composition of proteins)

Gompertz growth equation
J 26(1): 161 (comparison with von Bertalanffy equation)

Gonads (*see* Ovary; Testes)

Gonyaulax (Dinoflagellates)
B 168 : 14; 169: 151 (*G. acatenella* & possibly also *G. catenella* as cause of toxicity in B.C. shellfishes)
S 1320 (humic substances effect on growth)

Gorbman, Aubrey
J 26(8): 2111 (salmon olfactory discrimination)
(8): 2123 (salmon olfactory responses)

Gould, Edith
J 26(12): 3175 (αGPdH as index of iced haddock age)

Grampus griseus (*see* Dolphin, Risso's)

Gray, John Robson Allan
J 26(2): 399 (stream temperature)

Graybill, James Roger
J 26(5): 1400 (steelhead trout)

Grayling, arctic (*Thymallus arcticus*)
J 26(2): 325 (transplanted into Alta.)

Grazing
J 26(6): 1485 (re zooplankton production, Ogac L., Baffin Is.)

Great Lakes (*see also* names of individual Great Lakes)
J 26(2): 456 (uniformity of rainbow trout phenotypes upper lethal temperature)
B 151(F) (processing of commercial fishes)

Great Slave Lake, N.W.T.
J 26(8): 2260 (*Triaenophorus crassus* in arctic lampreys)

Green, W. A.
S 1349 (isolation of tropomyosin)

Greenberg, David Alexander
J 26(11): 2775 (M_2 tide modification due to Bay of Fundy barriers)

Greeneye, shortnose (*Chloropthalmus agassizi*)
J 26(2): 469 (range extension & morphometrics, off SW N.S.)
(10): 2694 (recent catches & range extension off N.S.)

Greenland
T 134 (Atl. salmon stocks: parasite indicator species for distinguishing from N American & European)

Greenland Current, East
J 26(2): 305 (zooplankton biomass)

Greenling, kelp (*Hexagrammos decagrammus*)
J 26(9): 2319 (parasites, B.C.)

Greenling, rock (*Hexagrammos superciliosus*)
J 26(9): 2319 (parasites, B.C.)

Greenling, whitespotted (*Hexagrammos stelleri*)
J 26(9): 2319 (parasites, B.C.)

Grenadier, roughead (*Macrourus berglax*)
J 26(2): 311 (copepod parasitic on fins)

Grey (*see* Gray)

Gribble (*Limnoria lignorum* and *L. tripunctata*) (isopods)
A 117 (biology)

Grimm, Andrew Spalding
J 26(7): 1823 (sodium transport re 1α-hydroxycorticosterone)

Grinols, Richard Byron
J 26(5): 1237 (new species of *Acantholiparis*)

Grinyer, Ivan
J 26(3): 629 (*Aeromonas salmonicida* phages)

Groundfish (Atlantic) (*see also* Fisheries; *also* names of commercial Atlantic groundfishes)
CJG 16 (investigations & landings, Nfld., 1968; landings, 1953–68)
T 102 (underwater observations from submarine)
125 (engineering performance data on otter trawls for)
A 132 (FRB research on)
137 (FRB & Canadian ICNAF research on Nfld.)

Groundfish (Pacific) (*see also* names of commercial species)
T 105 (life history, etc.)
113 (catches in research trawling off W coast Vancouver Is.)
117, 131 (taken in B.C. commercial trawl fishery, 1968)
135 (length–weight relations of 6 B.C. species)

Groves, Alan Brown
J 26(7): 1956 (tank to simulate reservoir conditions)

Growth (*see also* Age; Development; Size; Weight)
J 26(1): 161 (comparison of Gompertz vs. Bertalanffy curves for expressing growth in weight of 2 fish species)
(2): 229 (Babine L. sockeye salmon fry, from natural vs. artificial stream rearing)
(2): 389 (temperature & salinity effects on Dungeness crab larvae)
(3): 479 (size-selective mortality & sampling bias effects on estimates of)
(4): 741 (rate of *Schistocephalus solidus* cestode)
(4): 879 (trematodes found in Atl. argentine)
(4): 893 (2 hemiurid trematode species in pink & chum salmon)
(5): 1263; (6): 1625 (effect of finclipping on young Pac. salmons)
(5): 1289 (W L. Superior longnose suckers)
(6): 1485 (zooplankton, Ogac L., Baffin Is.)
(6): 1585 (differences between 2 Nfld. populations of landlocked Atl. salmon)
(6): 1631 (young chum salmon under different feeding regimes)
(8): 1969 (glass shrimp)
(8): 2252 (& age of N.W.T. broad whitefish)
(9): 2267 (review of Bertalanffy growth equation application to fishery management problems)
(9): 2363 (rate of young sockeye salmon re temperature & ration)
(9): 2403 (& age, blackbelly eelpout in Burrard Inlet, B.C.)
(9): 2493 (effect of lead, temperature, & oxygen fluctuations on brook trout)
(11): 2959 (salinity-induced changes in *Monochrysis lutheri* flagellate)
(11): 3069 (formulation of Bertalanffy growth curve)
(11): 3073 (derivation of average lengths of different fish age-groups)
(12): 3133 (SW Nfld. cod)
(12): 3237 (re ration of European plaice)
B 169 : 34 (Pac. oyster, B.C.)
T 88 (Atl. herring larvae re Bay of Fundy hydrography)
107 (sablefish reared in tanks)
108 (rock sole, N Hecate Strait, B.C.)
109 (yellowfin sole, Hecate Strait)
S 1318 (cod, W Nfld. stock)
1320 (*Gonyaulax* species; humic substances effect on)
1334 (factors controlling salmonid, in streams)
A 138 (queen crab)

Grubby (*Myoxocephalus aeneus*) (little sculpin)
J 26(6): 1689 (occurrences in Nfld. waters)

Gruchy, Charles George
J 26(6): 1467 (Canadian records of warty poacher)

Guanine (*see* Purines)

Gulls
J 26(4): 1103 (nematodes & other helminths from Australian)

Gunnel, crescent (*Pholis laeta*)
J 26(9): 2319 (parasites, B.C.)

Gunnel, penpoint (*Apodichthys flavidus*)
J 26(9): 2319 (parasites, B.C.)

Gunnel, saddleback (*Pholis ornata*)
J 26(9): 2319 (parasites, B.C.)

Gunnerød, Tor Bertel
J 26(3): 655 (salmon egg deposition)

Gupta, S. P.
J 26(4): 965 (*Acanthosentis cameroni* n.sp.)

Gutting
J 26(8): 2257 (hand shears for capelin)
B 151(F) (freshwater fishes)

Gymnothorax javanicus (*see* Eel, moray)

H

Habits (*see* Behaviour; Diel habits; Territorialism)

Haddock (*Melanogrammus aeglefinus*)
J 26(3): 519 (as an example of catch samples for population statistics computation)

(5): 1273 (feed, Gulf of St. Lawrence & N.S. Banks)
(12): 3175 (new enzymic activity test for freshness of ice-stored fresh gutted)
CHN 35 (blast freezing rates & weight loss, for fillets & pieces)
CJG 16 (Nfld. commercial landings, 1953–68 & 1968 details)
T 86 (trawl catches on Scotian Shelf & Georges Bank, 1965)
103 (in experimental otter-trawling, 1967)
S 1316 (size, age, & recruitment comparisons, Scotian Shelf)
1342 (aminotransferases in eggs & sperm)
A 119 (ICNAF 1967 Canadian research report on)

Haematozoa
J 26(4): 1075 (of N.B. & New England marine fishes)

Hagfish, black (*Eptatretus deani*) (*Polistotrema deani*)
J 26(12): 3246 (first B.C. record)

Hahn, William Eugene
J 26(8): 2111 (salmon olfactory discrimination)
(8): 2123 (salmon olfactory responses)

Haines, Terry Alan
J 26(1): 21 (bass response to shelter)

Hake, Pacific (*Merluccius productus*)
J 26(8): 1985 (stock & yield forecast, N Pac. Ocean)
(11): 2843 (role in Pac. sardine ecology; mathematical treatment)
(12): 3268 (transferrin variants)

Hake, silver (*Merluccius bilinearis*)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)
T 103 (in experimental otter-trawling, 1967)
A 119 (ICNAF 1967 Canadian research report)

Hake, white (*Urophycis tenuis*)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)
T 103 (in experimental otter trawling, 1967)
121 (used as example in computer program for predator study)
A 119 (ICNAF 1967 Canadian research report)

Halibut, Atlantic (*Hippoglossus hippoglossus*)
J 26(9): 2517 (temperature effect on dehydrogenase enzyme activity)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)

Halibut, California (*Paralichthys californicus*)
J 26(5): 1371 (NW range extension)

Halibut, Greenland (now Greenland turbot) (*Reinhardtius hippoglossoides*)
CJG 16 (Nfld. landings 1953–68, & details for 1968)
A 119 (ICNAF 1967 Canadian research report on)

Halibut, Pacific (*Hippoglossus stenolepis*)
J 26(9): 2351 (blood serum transferrin systems & hemoglobins)
CVG 41 (weight changes during holding in refrigerated sea water vs. ice)

Halifax County, N.S.
J 26(10): 2703 (seaweeds preliminary survey)

Haliotis kamtschatkana (*see* Abalone)

Haliris spinosa (*see Verticordia spinosa*)

Halliday, Ralph Gilmore
J 26(2): 469 (*Chlorophthalmus agassizi* off N.S.)
(10): 2691 (mesopelagic & other fishes from Canadian Atl.)
S 1348 (Clyde Sea area rare fishes)

Halsey, Thomas Gordon
J 26(7): 1763 (meromictic lakes changes)

Halver, John Emil
J 26(1): 111 (coho folic acid anemia)

Hamilton, Andrew Lloyd
J 26(6): 1667 (separating invertebrates from sediments)
(6): 1685 (collecting stream insects)
T 124 (Nearctic Chironomidae classification)

Hansen, Roy Penrose
S 1323 (composition of pristanic acids)

Hargrave, Barry Thomas
J 26(8): 2003 (Marion L. benthic primary production)

Harling, Wayne Robert
T 113 (*G. B. Reed* groundfish cruise 69-1)

Harmon, T. J.
T 130 (factors affecting Nfld. streams)

Harper, Peter
S 1268 (Que. stoneflies distribution)

Hartt, Allan Charles
S 1302 (N Pac. Ocean salmon)

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Harvesting (*see also* Apparatus; Fisheries; Nets; Traps; Trawl; etc.)
B 169 : 100 (Pac. oyster, B.C.)

Harvey, Harold Henry
J 26(3): 633 (white sucker age)

Hasler, Arthur Davis
J 26(8): 2173 (white bass orientation)

Hatchery (*see also* Culture (vertebrates); Eggs)
S 1335 (genetic variations in salmonids a possible result of managed populations)

Hatchetfish, silvery (*Argyropelecus lynchus lynchus*)
J 26(10): 2691 (recent record, La Have Bank off N.S.)

Haustoriidae (sand-burrowing amphipods)
J 26(2): 361; (5): 1321; (9): 2283 (studies of 5 Cape Cod species)

Haustorius canadensis (amphipod)
J 26(2): 361 (ecology, life history, behaviour)
(9): 2283 (physiological tolerances & behaviour responses to 5 environmental factors)

Hayward, Michael Joseph
J 26(12): 3217 (cod & flounder bacteria counts)

Heading (beheading)
J 26(8): 2252 (special hand shears for capelin)

Healey, David Andrew
T 106 (Ocean Station P oceanographic data time distribution)

Heart (*see also* Blood)
J 26(7): 1847 (physiological consequences of brook trout aortic catheterization)
(9): 2425 (progressive changes in carp ventral aorta re arteriosclerosis)
(10): 2561 (weight in white whales)
(11): 3049 (lactate dehydrogenase isoenzymes in dace tissue)

Heat content (*see also* Caloric content)
J 26(8): 2135 (L. Ontario, re crustacean plankton distribution)

Heaton, LeRoy H.
J 26(3): 707 (stains for use in oyster pathology)

Hecate Strait, B.C.
T 108 (rock sole population studies)

Heinle, Donald Roger
J 26(1): 150 (calanoid copepods culture)

Helicolenus dactylopterus (*see* Rosefish, blackbelly)

Hematin; Hematology (*see also* Blood)
J 26(9): 2299 (as catalyst of marine flesh lipids oxidation)
(11): 2881 (largemouth & smallmouth buffalofish hematology)

Hemilepidotus hemilepidotus (*see* Irish lord, red)

Heming Lake, Man.
J 26(4): 821 (*Triaenophorus nodulosus* in yellow perch)
(12): 3266 (diel activity periods of northern pike, whitefish, walleye, & white sucker)

Hemiptera
J 26(12): 3101 (Crecy L., N.B.)

Hemiuridae (*see also* Trematoda)
J 26(9): 2319 (list of species found in B.C. marine fishes)

Hemoglobin (*see also* Blood; Hematin)
J 26(9): 2299 (as catalyst of marine flesh lipids oxidation)
(9): 2351 (Pac. halibut, re transferrin phenotypes of serum proteins)

Henderson, Herman Francis
J 26(8): 2173 (white bass orientation)

Henderson, Nancy Elizabeth
J 26(2): 325 (S Alta. fishes)

Herbicides
J 26(5): 1378 (water pollution detection by spinner culture of mouse fibroblast cells)

Heredity (*see also* Genes)
J 26(9): 2351 (re Pac. halibut blood serum transferrins)
(10): 2633 (re sablefish muscle proteins polymorphism & population parameters)

Herlinveaux, Richard Henry
T 99 (Saanich Inlet, B.C., water movement)

Hermaphroditism
J 26(7): 1965 (sand dollar)
(9): 2521 (lake whitefish)

Herold, Richard Carl
J 26(7): 1965 (sand dollar, *Echinarachnius parma*)

Herring, Atlantic (*Clupea harengus* (*harengus*))
J 26(3): 597(F) (retinal structure re activity, etc.)
(6): 1577 (free fatty acids origin in commercial oils)
(7): 1889 (similarity of otolith nuclei in spring- and autumn-spawning, Gulf of St. Lawrence)
(7): 1919, 1923 (lipids extraction for preparation of protein concentrate)

(8): 2077 (swim bladder, etc. re buoyancy adjustment)
CJG 16 (Nfld. landings, 1967–68; distribution & migrations)
T 79 (fat contents, & content re length & season)
88 (spawning, & larval distribution, survival & growth re Bay of Fundy hydrography)
94–97 (Nfld. sampling data & summary tabulations, 1964–65 to 1967–68)
114 (chemical & nutritive characteristics of meals)
139 (catch statistics, length & age composition, in Gulf of St. Lawrence)
S 1283 (Nfld. fishery, re its resource)
1342 (aminotransferases in eggs & sperm)
1350 (oil & lipids extraction during fish protein concentrate processing; also lipids composition)
A 119 (ICNAF 1967 Canadian research report on)
124–126 (use for fish protein concentrate)
132 (FRB research on)

Herring, lake (*Coregonus artedii*) (cisco; tullibee)
J 26(4): 849 (*Cystidicola* nematodes in swim bladder)
(7): 1934 (distinction from *C. zenithicus*, Barrow L., Alta.)
(10): 2681 (shape & structure re gillnet selectivity)
B 151(F) (smoking)

Herring, Pacific (*Clupea* (*harengus*) *pallasi* (*i*))
J 26(8): 2077 (swim bladder, etc. re buoyancy adjustment)
(8): 2219 (larvae as feed of juvenile Pac. salmons)
(9): 2319 (parasites, B.C.)
CVG 42 (pump water clarification & solids recovery)

Hexagrammos decagrammus (*see* Greenling, kelp)
stelleri (*see* Greenling, white-spotted)
superciliosus (*see* Greenling, rock)

Hexamita inflata (flagellate protozoan)
S 1285 (axenic cultivation from Atl. oyster)

Hierops arctica (*see* Lanternfish, bigeye)

Hiltz, Doris Isabel
J 26(6): 1597 (swordfish muscle nucleotide degradation)
(8): 2027 (Nfld. capelin composition)

Hingley, Helen Joyce
J 26(6): 1577 (herring oils free fatty acids)

Hinnites multirugosis (*see* Scallop, purple-hinged rock)

Hiodon alosoides (*see* Goldeye)

Hippoglossoides elassodon (*see* Sole, flathead)
platessoides (*see* Plaice, American)

Hippoglossus hippoglossus (*see* Halibut, Atlantic)
stenolepis (*see* Halibut, Pacific)

Hirudinea (leeches)
J 26(4): 805 (*Calliobdella nodulifera* on Nfld. dogfish)
(4): 833 (*Piscicola* sp. on yellow perch)
(8): 2016 (partitioning community respiration in a lake sediment)
(12): 3101 (of Crecy L., N.B.)

Histology (*see also* Cytology; Morphology)
J 26(3): 597(F) (retinal structure of 20 Atl. fishes)
(3): 633 (white sucker scales & fin rays, re aging)
(3): 671 (chum salmon scales, re aging)
(4): 805 (helminths from Nfld. fishes)
(4): 909 (acanthocephalan parasite in Atl. salmon)
(4): 941 (invasion route of dracunculoid nematode to sockeye swim bladder)
(4): 947 (3 *Diphyllobothrium* cestode (1 new) species)
(4): 965 (*Acanthosentis cameroni* new acanthocephalan species)
(4): 975 (*Bothrimonas* cestode)
(5): 1199 (chum & sockeye salmon pectoral fin rays re aging)
(6): 1451 (clam drill accessory boring organ)
(6): 1694 (Atl. salmon muscle damage from nylon gillnet)
(8): 2193 (rainbow trout subjected to organophosphate insecticide)
(8): 2215 (microsporidial infection cysts in English sole)
(9): 2425 (carp ventral aorta)
(9): 2521 (of hermaphroditic lake whitefish ovo-testis)
(9): 2535 (diplococci bacteria in Atl. salmon diseased kidney)
(10): 2659 (of oligochaete gut tissue re uptake of glycine)
(10): 2669 (ciliate & turbellarian parasites in intestine of sea urchin)
(11): 2785 (of winter flounder tissues re toxic effects of copper sulphate)
(11): 2975 (interrenal tissue of normal vs. gonadectomized sockeye salmon)

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(12): 3242 (lesions in ovaries of aged Atl. cod)
S 1292 (salmon gonadotropin-injected ovary & testes of hypophysectomized goldfish)
1340 (dexamethasone-injected adult sockeye salmon adrenocorticol & interrenal tissues)

History (*see also* Life history)
J 26(5): 1205 (American plaice fishery, Magdalen Shallows, Gulf of St. Lawrence)
(7): 1699 (sources & dates of brown trout introduction throughout world)
B 168 : 10, 56, 64 (paralytic shellfish poisoning in B.C.)
169 : 1 (Pac. oyster production, B.C.)
A 122 (B.C. whaling)
123 (Nfld. salmon fishery)
138 (queen crab fishery, Canadian Atl. coast)

Hitz, Charles Robert
J 26(11): 3094 (black rockfish in central N Pac.)

Hodder, Vincent Mackay
T 95 (Nfld. herring sampling data 1965–66)

Hodgins, Harold Osborne
J 26(1): 15 (isozymes in sockeye sera)

Holland, Geoffrey Leonard
J 26(8): 2223 (effect of storm growth on surge elevations)

Homarus americanus (*see* Lobster)

Homing (*see also* Migration)
J 26(5): 1243 (blinded & anosmic vs. normal cutthroat trout, Yellowstone L., Wyoming)
(8): 2111, 2123 (olfactory response of chinook & coho salmon to natural waters)
(8): 2173 (open-water orientation of white bass, as determined by ultrasonic tracking methods)

Hooks
J 26(9): 2527 (various, for deepsea line fishing)
(12): 3279 (re polychaete taxonomy)
S 1354 (development of rostellar, in *Paricterotaenia paradoxa* cestode)
A 120 (lures for swordfishing)

Hooper, Shirley Norma
S 1266 (LDD & DDD diastereoisomers of phytanic acid)
1351 (load effect in open-tubular GLC)

Hopkins, Charles Adrian
J 26(4): 741 (*Schistocephalus solidus*, a tapeworm)
(8): 2250 (*Ligula intestinalis* life cycle)

Hopkins, Thomas Lee
J 26(2): 305 (polar zooplankton biomass)

Hormones (*see also* Cortisol; Steroids)
J 26(5): 1147 (re pituitary cytology of sockeye salmon after gonadectomy)
(7): 1789 (estrogens & cortisol effects on cortisol secretion of gonadectomized female sockeye salmon)
(7): 1837 (ACTH localization in sockeye salmon pituitary)
(11): 2975 (interrenal tissue hypertrophy of sexually maturing sockeye salmon re gonadectomy)
S 1292, 1336 (salmon pituitary gonodotropin restoration of sexual activity in hypophysectomized goldfish)
1308 (binding by fish plasma proteins)
1338 (androgens effect on cortisol distribution & secretion in gonadectomized male sockeye salmon)
A 135 (endocrinology levels effect on *Orconectes virilis* crayfish moulting photoperiod)

Horrall, Ross Moody
J 26(8): 2173 (white bass orientation)

Horton, Howard Franklin
J 26(5): 1400 (steelhead trout)

Hoskins, Gary E.
S 1297 (salmon egg structure & enzymatic degradation)

Houde, Edward Donald
J 26(6): 1647 (larval swimming ability)

Hourston, Alan Stewart
T 94–97 (Nfld. herring sampling data 1964–68)
S 1283 (Nfld. herring fishery)

Houston, Arthur Hillier
J 26(7): 1847 (aortic catheterization re trout)

Hoyle, Richard James
T 93 (freezing sperm of Atl. salmon)

Hudson Bay and James Bay
J 26(8): 2201, 2205 (white whale wintering & tagging)

Hughes, Roger Neville
J 26(7): 1959 (caloric content of marine sediments)

Humic substances
S 1320 (effect on *Gonyaulax* growth)

Humphreys, Robert David
T 94 (Nfld. herring sampling data 1964–65)

Hungar, Linda Dale
T 123 (clearing & staining salmon)

Hunter, Robert Comstock
J 26(7): 1939 (rainbow trout uptake of dieldrin)

Hunt, Robert Leroy
J 26(6): 1473 (brook trout overwinter survival)

Huron, Lake (*see* Great Lakes; Parry Sound; South Bay)

Hwang, Pei Chu
J 26(2): 413 (salmon seminal components)

Hyas coarcticus (*see* Crab, toad)

Hybognathus hankinsoni (*see* Minnow, brassy)
nuchalis (*see* minnow, silvery)

Hybopsis (*see Couesius*; *Platygobio*)

Hybridization
J 26(11): 3049 (tissue enzymes of blacknose × longnose dace)
(12): 3183 (between red & black threespine sticklebacks)
B 169 : 8 (possibilities for Pac. oysters)

Hydrocarbons
S 1286 (pristane & squalene content of eulachon oil)

Hydrodynamics
J 26(9): 2477; (11): 2775, 2887 (re Bay of Fundy tidal energy exploitation)

Hydroelectric energy (*see* Tides)

Hydrogen sulphide (*see* Sulphur compounds)

Hydrography (*see also* Limnology; Oceanography)
J 26(1): 171 (changes in Malpeque Bay, P.E.I., re oyster culture)
(2): 305 (zooplankton biomass re Arctic Basin & East Greenland Current)
T 88 (Bay of Fundy, re herring biology)
98 (Little Codroy R. & estuary, Nfld.)
S 1353 (Gulf of St. Lawrence sediments)
A 119 (ICNAF 1967 Canadian research report)

Hydrolagus affinis (*see* Chimaera, deepwater)

Hygophum hygomi and *H. macrochir* (lanternfishes)
J 26(10): 2691 (first Canadian records)

Hypophysectomy (*see* Pituitary)

Hynes, Hugh Bernard Noel
J 26(2): 279 (benthic invertebrates)

Hypoxanthine (*see* Purines)

Hypoxia (*see* Oxygen, dissolved)

I

Ice; Icing
J 26(10): 2727 (fatty acids reaction with Atl. cod muscle protein aged in ice then cold stored)
(12): 3175 (new test for iced age of fresh gutted fish)
B 169 : 98 (re B.C. oyster culture)
CVG 41, 44 (vs. refrigerated sea water re weight changes of some B.C. fishes)
A 138 (queen crab on vessel)

Ice island, drifting
J 26(2): 305 (zooplankton biomass observed during Arctic basin and East Greenland Current drift)

Icelinus filamentosus (*see* Sculpin, threadfin)
tenuis (*see* Sculpin, spotfin)

Icelus bicornis (*see* Sculpin, twohorn)

Ichthyoplankton (*see also* names of adult forms of fishes)
J 26(8): 2240 (sampling net for)

Ichthyopterin (*see* Pteridines)

ICNAF (*see* International Commission for the Northwest Atlantic Fisheries)

Ictalurus nebulosus (*see* Bullhead, brown)
punctatus (*see* Catfish, channel)

Ictiobus bubalus (*see* Buffalofish, smallmouth)
cyprinellus (*see* Buffalofish, bigmouth)

Identification (*see also* Keys; Speciation)
J 26(1): 175 (of northern pike vs. maskinonge fillets, etc.)
(2): 221 (of 2 similar triclad turbellarians)

Idler, David Richard
J 26(2): 413 (salmon seminal components)
(7): 1823 (sodium transport re 1α-hydroxycorticosterone)
(12): 3254 (improved extender for freezing Atl. salmon spermatozoa)
T 93 (freezing sperm of Atl. salmon)
S 1264 (Alaskan king crab & N Atl. queen crab sterols)
1308 (plasma proteins of fish)
1313 (carilaginous fish body fluids)
1325 (1α-hydroxycorticosterone in vivo and in vitro)

1329 (steroid desmolase in a marine invertebrate)
1352 (cod fishery)
A 124 (Halifax process development & scope)

Illex illecebrosus (*illecebrosus*) (*see* Squid, short-finned)

Illumination (*see* Light, reactions to)

Immunology
J 26(1): 1 (lobster re gaffkemia infection)
(1): 115 (coho salmon and rainbow trout resistance to bacterial endotoxins)
(5): 1392 (lobster hemolymph foreign protein disposal)
(7): 1837 (re ACTH & prolactin localization in sockeye salmon pituitary)
(9): 2511 (re infective virus of pancreatic necrosis in rainbow trout)

Inconnu (*Stenodus leucichthys*)
B 151(F) (smoking; canning)

Indicator species
J 26(4): 879 (trematodes, re Atl. fishes)
(4): 909 (*Pomphorhynchus laevis* acanthocephalan)
T 134 (various parasites, for Atl. salmon stocks)
S 1302 (of parasites re high seas chum salmon origin)

Infection (*see* Disease; Furunculosis; Gaffkemia; Immunology; Parasites)

Injury
J 26(6): 1694 (Atl. salmon muscle, from nylon gillnetting)

Inosine (*see also* Purines)
J 26(10): 2621 (re critical freezing zone of Atl. cod muscle)

Inosinic acid
S 1289 (biosynthesis in Pac. salmon & rainbow trout)

INPFC (*see* International North Pacific Fisheries Commission)

Insecticides (*see also* Pesticides; Pollution; Toxicants)
J 26(1): 47 (DDT in vitro degradation by Atl. salmon intestinal contents)
(7): 1939 (dieldrin uptake by perfused rainbow trout gills)
(8): 2193 (Dylox organophosphate effect on rainbow trout larvae)
(9): 2395 (resistance of resistant vs. nonresistant mosquitofish to 28 kinds of)
(12): 3209 (DDT lack of effect on hepatic dehydrogenase activity in young rainbow trout & coho salmon)
S 1324 (DDT sublethal effects on brook trout nervous system)

Insects, aquatic (*see also* classifications; *also* Insecticides)
J 26(2): 279 (upstream movements of river larvae)
(5): 1157 (feed, habits, communities, etc. in a small Que. stream)
(6): 1685 (emergence trap for collecting in streams)
(12): 3101 (of Crecy L., N.B.)
T 130 (of Nfld. streams)

Instruments (*see* Apparatus)

Integument
J 26(1): 1 (lobster: as defense against *Gaffkya homari* infection)

Intensity of fishing (*see* Catches; Exploitation; Fisheries)

International Commission for the Northwest Atlantic Fisheries (ICNAF)
S 1279–1284, 1316–1318 (reports of Canadian research)
A 119 (reports of Canadian research)

International North Pacific Fisheries Commission (INPFC)
S 1302 (chum salmon in offshore waters)

Interrenal tissue (*see* Adrenaline; Kidney; Pituitary)

Intestine
J 26(1): 47 (bacteria of Atl. salmon degrades DDT insecticide)

Invertebrates (aquatic marine in general) (*see also* classifications and names of species)
J 26(6): 1667 (fluorescent dyes for separating from sediments)
(9): 2319 (list of parasites found in B.C. marine fishes)
(12): 3101 (list of, in Crecy L., N.B.)
T 103, 122 (taken during Atl. otter-trawl surveys, 1967 & 1968)
S 1328 (synopsis of Canadian cephalopods)

Iodine compounds
J 26(9): 2311 (providone-iodine as disinfectant against *Aeromonas liquefaciens* in trout eggs)
T 114 (iodine content of Atl. & Pac. herring meals)

Irish lord, red (*Hemilepidotus hemilepidotus*)
J 26(4): 799 (new digenetic trematode species from)
(9): 2319 (parasites, B.C.)

Irish moss (*Chondrus crispus*)
J 26(10): 2703 (Halifax Co., N.S.)

Iron compounds (*see also* Hematin; Hemoglobin)

J 26(9): 2299 (effect on marine muscle lipids oxidation)
T 114 (iron content of Atl. & Pac. herring meals)

Irradiation (*see* Energy, radiant; Light, reactions to; Radioactivity)

Irwin, Brian
J 26(9): 2345 (zooplankton biomass equivalents)

Isopoda
J 26(9): 2319 (*Livoneca californica* on B.C. shiner perch)
T 117 (*Limnoria* biology)

Isopropanol
J 26(7): 1919, 1923 (water mixtures for lipids extraction in preparing fish protein concentrates)

Isopsetta isolepis (*see* Sole, butter)

J

Jahn, Lawrence Allan
J 26(5): 1243 (cutthroat trout movements and homing)

James Bay (*see also* Hudson Bay)
J 26(8): 2205 (white whales wintering in)

Jangaard, Peter Michael
S 1352 (Atl. cod fishery)
A 127 (high priority fish protein concentrate development)

Japan
B 169 : 82 (culture & export of Pac. oyster seed)

Jaroszynski, Lubomir Oswald
J 26(8): 2240 (otter surface sampler)

Jellyfishes (*see also* Medusae)
J 26(7): 1743 (experiments re feeding habits)

Jenkins, Thomas Mandeville, Jr.
J 26(12): 3275 (brown and rainbow trout night feeding)

Jenkinson, Donald William
J 26(5): 1199 (pectoral fin rays re salmon age)
CNS 27 (age composition of 1965 B.C. sockeye, chum, & pink salmon)

Jennings, Joseph Brian
J 26(10): 2669 (nutrition & chemical composition of *Syndesmis franciscana*, & taxonomy of *S. antillarum*)

Jhingran, Vishwa Gopal
J 26(11): 3073 (derivation of average lengths of different age-groups of fishes)

Joergensen, Ole Halling
T 106 (Ocean Station P oceanographic data time distribution)

Johnson, Eugene Allen
J 26(8): 2245 (*Mytilicola orientalis* fecundity)

Jonas, Richard Edmund Ernest
J 26(8): 2237 (free fatty acid formation)

Jonkel, Charles Joseph
J 26(8): 2205 (white whales wintering)

Jordan, Carol
J 26(2): 461 (rainbow trout ovary cells)
(5): 1378 (spinner culture cells detect water pollution)

Jordan, Fred Paul
S 1296 (population estimates of salmon smolts)

Jordania zonope (*see* Sculpin, longfin)

Juan de Fuca Strait
J 26(1): 55 (benthic infauna standing crop)

K

Kabata, Zbigniew
J 26(2): 311 (4 Lernaeopodidae)
(4): 921 (*Phrixocephalus cincinnatus*)
(6): 1407 (Tanypleuridae fam.nov.)
(11): 2987 (revision of genus *Salmincola* Wilson, 1915)
(11): 3043 (*Chondracanthus narium* n.sp.)
S 1298 (*Salvelinema* Trofimenko buccal region structure)
1301 (*Praecidochondria galatheae* from a Malayan fish)
1306, 1307 (Copepoda parasitic on Australian fishes)

Kajaji, Vijay Laxmi
J 26(4): 967 (*Acanthosentis cameroni* n.sp.)

Kalff, Jacob
J 26(2): 463 (natural phytoplankton populations)

Kanazawa, Akio
S 1329 (steroid desmolase in a marine invertebrate)

Karnicka, Barbara
J 26(11): 2969 (chemical composition of shrimp flesh & nutritive value)

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Kates, Morris
S 1323 (composition of pristanic acids)

Ke, Paul Jenn
J 26(8): 2027 (Nfld. capelin composition)
(8): 2037 (Nfld. capelin lipids)
S 1339 (fluoride in biological samples)

Keepability (*see* Quality of fishery products)

Kennedy, Owen David
J 26(12): 3165 (zooplankton food in winter in Strait of Georgia)
T 110 (Strait of Georgia biological oceanographic observations)

Kennedy, William Alexander
T 107 (sablefish culture)

Kerekes, Joseph Jenõ
J 26(2): 460 (blackspotted stickleback in Nfld.)

Ketones
S 1331 (separation of multiple-branched by chromatography)

Keys
J 26(4): 965 (genus *Acanthosentis* Indian and African acanthocephalans)
(7): 1727 (Wash. & S B.C. Ophiuroidea)
(10): 2595 (new family: Acrocirridae polychaetes)
(11): 3017 (*Salmincola* parasitic copepod species)

Khouw, Boen Tie
S 1285 (*Hexamita inflata* axenic cultivation from *Crassostrea virginica*)

Kidney (*see also* Adrenaline; Pituitary)
J 26(3): 639 (corpuscles of Stannius re American eel renal physiology)
(9): 2535 (bacterial disease of hatchery vs. feral Atl. salmon)
(10): 2561 (weight in white whales)
(11): 2785 (copper sulphate toxicity effects on winter flounder)
S 1340 (stressed maturing sockeye salmon interrenal activity suppression by dexamethasone corticosteroid injection)

Killifish, Pacific (*Fundulus parvipinnis*) (California killifish)
J 26(10): 2643 (oxygen metabolism re body weight)

Killifish, striped (*Fundulus majalis*)
J 26(2): 433 (blood morphology)

Kitano, Yutaka
T 109 (age and growth of yellowfin sole)

Kitchell, James Frederick
J 26(7): 1801 (rainbow trout on pellet diets)

Knight, William Rexford
J 26(11): 3069 (formulation of von Bertalanffy growth curve when growth rate is roughly constant)

Ko, Ronald Chun
J 26(4): 849 (*Cystidicola* revision)

Kohler, Allan Carl
J 26(5): 1273 (cod & haddock food)

Kokanee (*Oncorhynchus nerka* (*kennerlyi*))
J 26(2): 325 (transplanted into Alta.)

Kolakowski, Edward
J 26(11): 2969 (chemical composition of shrimp flesh & nutritive value)

Kosaki, Thomas Iwao
J 26(8): 2208 (Pac. marine toxins: ciguatoxin not in vivo anticholinesterase)

Koski, K Victor
J 26(1): 133 (estimating salmonid survival)

Kramer, Donald Emerson
CVG 41 (weight changes in Pac. coast fish stored at sea)
43, 44 (storage of Pac. salmon at sea)

Krauel, David Paul
T 115 (Margaree & Cheticamp R., N.S., estuaries)
120 (Bedford Basin data report, 1967)

Kuntz, Robert Elroy
J 26(4): 793 (nematodes from Malaysia)

Kwain, Wen-hwa
J 26(3): 687 (trout bottom colour selection)
(12): 3233 (rainbow trout response to overhead light)

Kyte, Michael Allan
J 26(7): 1727 (ophiuroid synopsis and key)

L

Labrador (*see also* Newfoundland)
CJG 16 : 25 (cod landings, 1936–68)

Lactic acid; Lactates
J 26(1): 15 (blood serum lactate dehydrogenase isoenzymes variants in sockeye salmon populations)
(11): 3049 (5 dehydrogenase isoenzymes in tissues of longnose & blacknose dace & their hybrids)

Lagenorhynchus obliquidens (*see* Dolphin, Pacific striped)

LaHam, Quentin Nadime
J 26(8): 2193 (Dylox effects on trout larvae)

Lahiry, N. L.
J 26(3): 704 (canned shrimp compounds)

Laird, Marshall
J 26(4): 1075 (marine fish hematozoa)

LaLanne, John Joseph
J 26(3): 671 (chum scales re age)

Lamellibranchs (*see also* species)
B 168 : 30 (positive & negative toxicity tests in B.C.)

Lampanyctus alatus, L. festivus, and *L. pusillus* (lanternfishes)
J 26(10): 2691 (first Canadian records)

Lampanyctus leucopsarus (*see* Lanternfish, smallfin)

Lampetra japonica (*see* Lamprey, arctic)
lamottei (*see* Lamprey, American brook)
planeri (*see* Lamprey, western brook)

Lamprey, American brook (*Lampetra lamottei*)
J 26(11): 3077 (lampricides tests on)

Lamprey, arctic (*Lampetra japonica*)
J 26(8): 2260 (*Triaenophorus crassus* in Great Slave L.)

Lamprey, sea (*Petromyzon marinus*)
J 26(9): 2413 (re survival of planted lake trout, South Bay, L. Huron)
(11): 3077 (larvicide evaluation, Big Garlic R. & Saux Head L., Michigan)
B 151(F) (smoking)
T 103 (taken in Atl. otter-trawl survey)

Lamprey, western brook (*Lampetra planeri*)
J 26(12): 3252 (spawning behaviour)

Lampritrema nipponicum (trematode)
S 1287 (parasite in Atl. argentine stomach)

Lander, Robert Harry
J 26(5): 1383 (swimming thrust of sockeye salmon re selectivity of gillnets)

Landings (*see* Catches)

Langford, Robert Wesley
S 1337 (adrenalectomy of the eel)

Lanternfish, bigeye (*Hierops arctica*) (*Electrona arctica*)
J 26(10): 2691 (first Canadian record since 1910)

Lanternfish, glacier (*Benthosema glaciale*)
J 26(10): 2694 (catches off La Have Bank, N.S.)

Lanternfish, horned (*Ceratoscopelus maderensis*)
J 26(10): 2691 (recent catches off N.S.; diurnal depth distribution)

Lanternfish, Krøyer's (*Notoscopelus krøyeri*)
J 26(10): 2691 (recent catches off N.S.; diurnal depth distribution)

Lanternfish, largescale (*Symbolophorus veranyi*)
J 26(10): 2697 (8 recent specimens off N.S.)

Lanternfish, patchwork (*Notoscopelus resplendens*)
J 26(10): 2691 (first Canadian Atl. record)

Lanternfish, smallfin (*Stenobranchius* (*Lampanyctus*) *leucopsarus*)
J 26(8): 2211 (re feed of yellowtail rockfish)

Lanternfish, spotted (*Myctophum punctatum*)
J 26(10): 2691 (recent catches off N.S.; diurnal depth distribution)

Lanternfishes
J 26(10): 2691 (new or recent Canadian Atl. coast records, some indexed herein by scientific names only)

Lantz, Andrew William
B 151(F) (special products from freshwater fishes)

Lardeau River, B.C.
J 26(1): 33 (rainbow trout lakeward migration behaviour in upper)

Larkin, Peter Anthony
J 26(5): 1372 (fish school size & migration)
(10): 2715 (simulated long-term environmental fluctuations on maximum sustained yield)
S 1271 (sockeye population biology)

Larvacea
J 26(8): 2219 (*Oikopleura* in juvenile Pac. salmon feed)

Lau, Yan Chee
J 26(7): 1857 (trout muscle lipase)

Lauzier, Louis Marcel
J 26(12): 3248 (larval swordfish from W Atl.)
T 136 (larval swordfish in W Atl.)

Lawler, George Herbert
J 26(4): 821 (*Triaenophorus nodulosus* in yellow perch)
(12): 3266 (Heming L. fishes activity periods)

Lawrence Creek, Wisconsin
J 26(6): 1473 (overwinter survival of wild brook trout fingerlings)

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Lead compounds
J 26(9): 2493 (effect on brook trout growth)
A 124 : 49 (in fish protein concentrates)

Lebbeus (hippolytid shrimps)
J 26(7): 1899 (*L. polaris* & *L. groenlandicus* in W Canadian arctic)

Le Brasseur, Robin John
J 26(6): 1631 (juvenile chum salmon growth)
S 1295 (ocean survey discussion of critical indices)

Lecithaster gibbosus (hemiurid trematode)
J 26(4): 813 (in early sea life of pink salmon)
(4): 893 (biology in pink & chum salmon)
(9): 2913 (common parasite of B.C. fishes)

Lee, Agnes Siu-King
J 26(5): 1185 (salmon skin purines & pteridines)

Leech
J 26(4): 805 (*Calliobdella nodulifera* on Nfld. dogfish)

Lee's phenomenon
J 26(3): 479 (re selective mortality & biased sampling effects)

Legendre, Rosaire
J 26(12): 3271 (freeze-dried cod steaks quality)

Leggett, William Claude
J 26(6): 1585 (Nfld. landlocked Atl. salmon)
(11): 3091 (landlocked Atl. salmon pugheadedness)

Length (*see also* Growth; Size; Weight)
J 26(1): 123 (allometric length–weight regression model)
(1): 143 (Greenland sharks, N Baffin Is.)
(5): 1289 (length–weight relation, longnose sucker)
(5): 1301 (distribution, Nfld. American plaice)
(10): 2561 (white whale from various localities)
(10): 2741 (re weight for rapid average weight estimation of young sockeye salmon)
(11): 3073 (derivation of average lengths of different fish age-groups)
(12): 3133 (cod off SW Nfld.)
B 171 (B.C. whales)
T 79 (re Atl. herring fat content)
94–97 (frequency data, Nfld. herring, 1964–65 to 1967–68)
108 (rock sole, N Hecate Strait, B.C.)
129 (computer program for statistical analysis of length-frequency data; northern pike used as example)
135 (length–weight relations for 6 B.C. groundfish species)
139 (frequency distribution & age–length ratios, Gulf of St. Lawrence herring)
S 1317 (re weight & age of salmon off Nfld.)
1318 (composition, W Nfld. cod stock)

Leong, Roderick Jsun Hong
J 26(3): 557 (anchovy feeding)

Lepidophyllum cameroni (trematode)
J 26(4): 799 (new digenetic species, from red Irish lord, B.C.)

Lepidopsetta bilineata (*see* Sole, rock)

Lepomis macrochirus (*see* Bluegill)

Leptocottus armatus (*see* Sculpin, Pacific staghorn)

Leptodora kindtii (a cladoceran)
J 26(8): 2135 (horizontal distribution in L. Ontario)

Lernaeoceridae (copepods)
J 26(4): 921 (*Phrixocephalus cincinnatus* biology)

Lernaeopodidae (parasitic copepods)
J 26(2): 311 (4 species on Nfld. & W Greenland fishes)
(11): 2987 (revision of *Salmincola* genus)
S 1307 (6 species (4 new) parasitic on Australian fishes)

Lesions (*see* Disease)

Lethal limits
J 26(2): 456 (upper temperature, for Great Lakes rainbow trout)
(6): 1473 (temperature, re wild brook trout fingerling winter survival)
(9): 2283 (5 haustoriid amphipod species re 5 environmental factors)

Leucichthys (*see Coregonus*)

Leung, Tec C.
S 1349 (isolation of tropomyosin)

Levings, Colin David
J 26(9): 2403 (*Lycodopsis pacifica* in B.C.)

Lewis, Alan Graham
J 26(5): 1347 (*Euchaeta japonica* development)

Li, Ming Fang
J 26(2): 461 (rainbow trout ovary cells)
(5): 1378 (spinner culture cells detect water pollution)
S 1288 (study of lobster using serum protein concentration)

Library
T 90 (determining periodical selection policy for a freshwater biological research)

Lice (*see* Amphipoda; Copepoda, parasitic; Parasites; Salmon-lice; Whale-lice)

Lie, Ulf
J 26(1): 55 (Puget Sound benthic infauna)

Life cycle (*see* Life history)

Life history (*see also* aspects of; *also* names of organisms)
J 26(2): 361; (5): 1321 (5 Haustoriidae amphipod species)
(4): 717 (*Diphyllobothrium pacificum*)
(4): 831 (infection dynamics of *Triaenophorus nodulosus* in yellow perch)
(4): 833 (various parasites of yellow perch)
(6): 1485 (zooplankton, Ogac L., Baffin Is.)
(10): 2543 (various planktonic copepods, Parry Sound, Ont.)
T 105 (several important B.C. groundfish species)
A 131(F) (swordfish)

Life span (*see* Longevity)

Light, reactions to (*see also* Diel habits; Eye; Vision)
J 26(1): 21 (yearling smallmouth bass)
(1): 33 (lakeward migrating young rainbow trout)
(2): 279 (re benthic invertebrates upstream river movements)
(2): 463 (re phytoplankton photosynthesis diel periodicity and efficiency re light intensity)
(3): 583 (re Atl. cod feeding behaviour)
(3): 687 (re rainbow trout bottom colour selection)
(8): 2093 (re Atl. salmon parr & smolt buoyancy)
(8): 2250 (accelerating hatching of cestode eggs)
(11): 2959 (effect on flagellate growth & photosynthesis)
(12): 3233 (rainbow trout response to overhead, re age and intensity)
(12): 3266 (re catchability of 4 fish species, Heming L., Man.)
S 1333 (negative phototaxis of emerging sockeye salmon fry)
A 135 (photoperiod of *Orconectes virilis* crayfish moulting)

Light, William John
J 26(11): 3088 (*Manayunkia aestuarina* in B.C.)

Lighthart, Bruce
J 26(2): 299 (bacteriovorous Protozoa)

Lightner, Donald
J 26(8): 2247 (virus in trout pancreatic tissue)

Ligula intestinalis (*see* Cestoda)

Limanda aspera (*see* Sole, yellowfin)
ferruginea (*see* Flounder, yellowtail)

Limnocalanus macrurus
J 26(10): 2543 (life cycle & vertical distribution, Parry Sound, Ont.)

Limnodrilus hoffmeisteri (tubificid oligochaete)
J 26(10): 2659 (nutritional resources in Toronto harbour sediments)

Limnology (*see also* Benthos)
J 26(5): 1157 (of small Que. stream re aquatic insects)
(5): 1363 (Owikeno L., B.C., re sockeye salmon production)
(7): 1763 (of 4 southern B.C. meromictic lakes)
(7): 1948 (2 useful devices for vertical plankton & water sampling)
(12): 3101 (Crecy L., N.B., before and after fertilization)
T 90 (determining periodical selection policy on, for a library)

Limnoria lignorum; *L. tripunctata* (*see* Gribble)

Lingcod (*Ophiodon elongatus*)
J 26(9): 2319 (parasites, B.C.)
(11): 3043 (new copepod species from nasal cavity)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 105 (life history, feed, etc.)
117, 131 (B.C. commercial trawl landings, 1968)
135 (length–weight relations)

Liparid (new species) (*Acantholiparis caecus*)
J 26(5): 1237 (description; found off N Oregon coast)

Liparid, spinycheek (*Acantholiparis opercularis*)
J 26(5): 1237 (range extension S to Oregon coast)

Lipase (*see* Enzymes; Lipids)

Lipids (*see also* Acids, fatty; Oils & fats; Phospholipids)
J 26(7): 1919, 1923 (extraction from Atl. herring for preparing protein concentrates)
(8): 2030, 2037 (content & fatty acids, also alterations during cold storage, of Nfld. capelin)

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(8): 2037 (fat content & lipid hydrolysis of capelin re sex)
(8): 2234 (content of Atl. salmon & canned Pac. salmon)
(8): 2237 (inhibitors for free fatty acids liberation from trout muscle lipids during cold storage)
(9): 2299 (promoters & inhibitors of oxidation of marine muscle)
(11): 2843 (content of steelhead trout during parr-to-smolt transformation)
S 1286 (content of eulachon oils)
1350 (extraction from Atl. herring material for fish protein concentrate; also lipids composition)
A 124, 125 (extraction & residual, fish protein concentrates)
130 (re fish muscle nutritional value & preservation)

Lissodelphis borealis (*see* Dolphin, northern right-whale)

Lists of organisms (*see* Benthos; Birds; Checklist; Fauna, aquatic; Fishes, lists of; Flora, aquatic; Invertebrates, marine; Keys; Parasites; Phytoplankton; Plankton; Zooplankton; etc.)

Lists of publications (*see* Bibliographies; Publications and reports)

Literature, limnological
T 90 (determining periodical selection policy for a library)

Little Codroy River, Nfld.
T 98 (climatic & geomorphic aspects)

Littorina saxitilis (*see* Periwinkle, rough)

Liver
J 26(10): 2561 (weight in white whales)
(11): 2785 (effects of copper sulphate poisoning on winter flounder)
(12): 3209 (effect of feeding & DDT on activity of glucose 6-phosphate dehydrogenase in fish liver)
B 151(F) (smoked & canned burbot)
S 1286 (squalene & pristine content of eulachon lipid)
1289 (de novo biosynthesis of inosinic & uridylic acids in Pac. salmon and rainbow trout)

Livoneca californica (*see* Isopoda)

Llewellyn, Jack
J 26(4): 1063 (monogean gill parasites)

Lobianchia dofleini (a lanternfish)
J 26(10): 2691 (recent N.S. records)

Lobster (*Homarus americanus*)
J 26(1): 1 (natural defenses against gaffkemia infection)
(3): 701 (mortality from unusually low P.E.I. estuarine salinity)
(5): 1392 (hemolymph disposal of foreign proteins)
(7): 1931 (larvae resistance to bleached kraft mill effluent)
(8): 2101 (protein serum changes during moult & reproduction)
(9): 2503 (temperature effect on gaffkemia resistance)
T 102 : 18, 36 (underwater observations from cubmarine)
103, 122 (in experimental otter-trawlings, 1967 & 1968)
S 1276–1278 (kraft mill effluent toxicity to larval & adult)
1288 (serum protein concentration of hemolymph as index of condition)
1344 (*Gaffkya homari* effects on physiology)
1346 (phospholipids biosynthesis)
A 121 (treating traps against shipworm attack)
136 (underwater observations from cubmarine)

Loligo pealeii (*see* Squid, longfinned)

Lolliguncula brevis (*see* Squid)

Longevity (*see also* Age)
J 26(4): 879, 893 (various trematodes)
(6): 1585 (differences between 2 Nfld. populations of landlocked Atl. salmon)

Lophius americanus (*see* Monkfish)

Lord, Esther Irene
S 1284 (Georges Bank scallop fishery)

Loring, Douglas Howard
J 26(1): 171 (Malpeque Bay, P.E.I., physiographic changes 1845–1955 re oyster production)
S 1353 (mineral dispersal patterns)

Lota lota (*see* Burbot)

Lucinoma annulata (*see* Clam, ringed lucina)

Lumpfish (*Cyclopterus lumpus*)
J 26(3): 597(F) (retinal structure re activity, etc.)

Lumpsucker, Pacific spiny (*Eumicrotremus orbis*)
J 26(12): 3262 (sexual dimorphism)

Lunatia heros (*see* Snail, moon)

Lungs
J 26(10): 2561 (weight in white whales)

Lures
A 120 (longline, for swordfishing)

Lycodes esmarki (*see* Eelpout, Esmark's)
lavalaei (*see* Eelpout, Laval's)
reticulatus (*see* Eelpout, arctic)
terra-novae (*see* Eelpout sp.?)
turneri (*see* Eelpout, polar)
vahlii (*see* Eelpout, Vahl's)

Lycodopsis pacifica (*see* Eelpout, blackbelly)

Lymphocytes (*see* Blood)

Lyons Lake, B.C.
J 26(7): 1763 (meromixis & other characteristics)

Lyonsiella quaylei (septibranchid bivalve)
J 26(8): 2230 (new NE Pac. species)

M

MacAskie, Ian Bruce
B 171 (B.C. marine mammals)

MacCallum, Wallace Allison
J 26(8): 2027 (Nfld. capelin composition)
(8): 2037 (Nfld. capelin lipids)
(8): 2257 (heading and gutting capelin)
(12): 3217 (cod & flounder bacteria counts)

MacCrimmon, Hugh Ross
J 26(3): 687 (trout bottom colour selection)
(7): 1699 (brook trout world range)
(12): 3233 (rainbow trout response to overhead light)

Macdonald, Peter Duncan Macgregor
T 129 (techniques for statistical analysis of length-frequency data)

Mackay, Isobel
J 26(11): 2795 (2 cyprinid fishes fecundity in R. Thames)

MacKay, Kenneth Tod
J 26(9): 2537 (Atl. salmon meristic analyses)
(10): 2769 (first records of *Ariomma bondi*, *Caranx crysos*, & *Selar crumenophthalmus* in Gulf of St. Lawrence)

Mackay, Rosemary Joan
J 26(5): 1157 (Mont St. Hilaire, Que., stream insect communities)

MacKelvie, Robin Maxwell
J 26(12): 3259 (infectious pancreatic necrosis in salmonids of Maritime Provinces)

Mackenzie River, N.W.T.
J 26(8): 2252 (broad whitefish age & growth)

Mackerel, Atlantic (*Scomber scombrus*)
J 26(9): 2537 (meristic analysis of N American coastal populations)
A 119 (ICNAF 1967 Canadian research report on)

Mackerel, horse (*Trachurus trachurus*)
J 26(10): 2697 (2 new Canadian Atl. specimens)

Mackerel, Spanish (*Scomberomorus maculatus*)
J 26(4): 713 (*Diphyllobothrium* tapeworm in Peruvian)

Macoma balthica (*see* Clams (Atlantic))
nasuta (*see* Clam, bent-nosed)

MacPhee, John Alden, Jr.,
J 26(5): 1375 (arctic shanny record Massachusetts Bay)

Macrochaeta (Polychaeta Sedentaria)
J 26(10): 2595 (transferred to new family Acrocirridae; new species *M. pege*; description of other species)

Macrourus berglax (*see* Grenadier, roughhead)

Madden, Jane Anne
J 26(7): 1847 (aortic catheterization re trout)

Magdalen Shallows, Gulf of St. Lawrence
J 26(5): 1205 (exploitation effects on American plaice stock)

Magnesium compounds
J 26(2): 413 (cation concentration in Atl. salmon semen)
(8): 2237 (sulphate as inhibitor of trout muscle lipid hydrolysis during cold storage)
T 114 (magnesium content of Atl. & Pac. herring meals)
S 1273 (partial molal volume of chloride, sulphate, bicarbonate, & nitrate in sea water)

Maillard browning (*see* Browning of fish flesh)

Maine, Gulf of
J 26(8): 1969 (glass shrimp)
(10): 2746 (water temperature conditions in & off, 1968)

Makow, David Mark
S 1269 (freshwater fish tissue properties)

Malacocottus kincaidi (*see* Sculpin, blackfin)

Mallotus villosus (*see* Capelin)

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Malonaldehyde
J 26(9): 2299 (indicator of lipids hydrolysis & oxidative rancidity)
S 1314 (reaction with cysteine & methionine)

Malouin, Rene
S 1268 (Que. stoneflies distribution)

Malpeque Bay, P.E.I.
J 26(1): 171 (physiographic changes re oyster culture)

Malpeque oyster disease
B 169 : 164 (nature & cause)
S 1285 (possible relation of *Hexamita inflata* protozoan to)

Man
J 26(4): 713 (*Diphyllobothrium pacificum* tapeworm in Peru)
B 168; 169: 151 (paralytic shellfish poisoning from B.C. shellfishes)
S 1266 (Refsum's disease)

Management (*see also* Hatchery; *also* names of International Commissions)
B 168 (B.C. commercial clam industry, re paralytic shellfish poisoning)
B 169 : 174, 178, 185 (Pac. oyster industry, B.C.)
T 108 (rock sole fishery, N Hecate Strait, B.C.)
S 1335 (production & genetic factors in managed salmonid populations)

Manayunkya aestuarina (polychaete)
J 26(11): 3088 (range extension to B.C.)

Manganese compounds
T 114 (content of Atl. & Pac. herring meals)

Manion, Patrick James
J 26(11): 3077 (lamprey larvicide evaluation)

Mann, John Howard
CVG 43 (storage of Pac. salmon at sea)

Mann, Kenneth Henry
J 26(11): 2795 (2 cyprinid fishes fecundity in R. Thames)

Manohar, Shiriram Vafudeo
J 26(5): 1368 (fish muscle fluorescence)

Mansfield, Arthur Walter
J 26(1): 143 (observations on Greenland shark)

Manter, Harold Winfred
J 26(4): 787 (3 new trematode genera)

Mantle (of squid)
J 26(6): 1676 (length re pen length of *Lolliguncula brevis*)

Manzer, James Ivan
J 26(8): 2219 (juvenile Pac. salmon stomach contents)

March, Beryl Elizabeth
T 114 (Atl. coast herring meals)

Margaree R., N.S.
T 115 (physical oceanography of estuary)

Margolis, Leo
J 26(4): 893 (2 hemiurid trematodes)
S 1267 (*Cystidicola, Metabronema,* & *Rhabdochona* review)
1298 (*Salvelinema* Trofimenko buccal region structure)
1299 (Pac. salmons swim bladder nematodes)
1300 (blood feeding in *Salvelinema walkeri,* a coho parasite)

Marion Lake, B.C.
J 26(6): 1605 (predation of zooplankton standing stocks by *Cyclops*)
(8): 2003 (epibenthic algal production & community respiration in sediments)

Marketing
B 169 : 138 (Pac. oyster, B.C.)
A 138 : 38 (queen crab)

Markert, John Richard
J 26(5): 1185 (salmon skin purines & pteridines)

Marking methods, returns, losses, and interpretation (*see also* Migration; Tagging)
J 26(2): 229 (sockeye salmon fry)
(5): 1263 (finclipping vs. tetracycline marking effects on sockeye salmon fingerling survival)
(6): 1619 (tests of fluorescent pigment vs. finclipping re coho salmon fry survival)
(8): 2173 (ultrasonic transmitter in white bass stomach, for tracking)
(10): 2765 (Pac. salmons & steelhead trout with die cooled by liquid nitrogen)
T 118 (etching identification on razor clam shell for population studies)
A 123 : 358 (Nfld. salmon)

Markov chain
J 26(11): 2843 (re stochastic model of interpopulation dynamics in marine ecology)

Marshall, Kenneth Eric
T 90 (literature citations of freshwater & fisheries biology)

Martin, William Robert
A 126 (fish resources utilization for fish protein concentrate)

Maskinonge (*Esox masquinongy*) (muskellunge)
J 26(1): 175 (distinguishing fillets or remains from those of northern pike)

Mason, John Christopher
J 26(1): 63 (coho fry hypoxial stress)

Masset, B.C.
T 118 (razor clam populations)

Mathematical treatment of data (*see also* Computer programming)
J 26(1): 123 (allometric weight–length regression model)
(1): 161 (comparison of 2 fish growth equations)
(2): 199 (estimating zooplankton production from phytoplankton production)
(2): 325 (DeLury population estimator robustness)
(3): 479 (effects of size-selective mortality on sampling bias)
(3): 655 (variance components in sockeye spawning potential)
(5): 1372 (fish school size re migration navigation)
(8): 2223 (rate of storm growth effect on subsequent oceanic surge elevations)
(9): 2267 (review of Bertalanffy growth equation application to fishery management problems)
(9): 2477 (hydrodynamics re, Bay of Fundy tidal barriers)
(10): 2643 (power function for oxygen consumption re body weight of several fishes)
(10): 2715 (effects of simulated long-term environmental fluctuations on maximum sustained yield)
(10): 2741 (weight on length regression for rapid average weight estimation of young sockeye salmon)
(11): 2843 (stochastic model of interpopulation dynamics in marine ecology, re Pac. sardine)
(11): 2887 (theory of tidal energy exploitation re Bay of Fundy)
(11): 3069 (Bertalanffy growth curve modification)
(12): 3237 (ration re growth of European plaice)
T 126, 128 (re mass transport of N Pac. Ocean waters)

Mathews, Stephen Barstow
J 26(6): 1619 (coho marking & finclipping)

Mathisen, Ole Alfred
J 26(3): 655 (salmon egg deposition)
(10): 2741 (weight & length measurements re estimation of average weight of juvenile sockeye salmon)

Mating (*see also* Reproduction)
J 26(10): 2737 (effects of delayed, on king crab reproduction)
(12): 3252 (behaviour, western brook lamprey)

Matter, particulate (*see also* Feed; Productivity, primary)
J 26(3): 557 (re northern anchovy feeding habits)
(12): 3165 (as winter zooplankton feed, Strait of Georgia, B.C.)
T 110 (Strait of Georgia, 1965–68)
S 1326 (organic, as substrate for heterotrophic bacteria, re primary productivity)
1345 (retention of by screens & filters)

Matton, Pierre
J 26(8): 2193 (Dylox effects on trout larvae)

Maturation; Maturity (*see also* Hormones)
J 26(4): 893 (2 hemiurid trematode species in pink & chum salmon)
(5): 1285 (W L. Superior longnose sucker)
(7): 1877 (E & W L. Erie walleyes)
(7): 1943 (winter flounder oocyte)
(12): 3133 (cod, off SW Nfld.)
T 94–97 (frequency data, Nfld. herring, 1964–65 to 1967–68)
105 (B.C. commercial groundfishes)
S 1310 (changes in sockeye salmon cortisol dynamics re sexual)
1318 (W Nfld. cod stock)
A 138 (queen crab size at)

Maurolicus muelleri (*see* Pearlsides, Müller's)

Mawson, Patricia Marietje
J 26(4): 1103 (nematodes re Australian gulls and terns)

May, Arthur William
S 1279 (research vessels comparative fishing)
1318 (biology & fishery of the W Nfld. cod stock)

Mayflies (*see* Ephemeroptera)

McAllister, Carey Douglas
J 26(2): 199 (zooplankton production; correction on J 26(8): 2264)

McAllister, Donald Evan
J 26(12): 3246 (*Eptatretus deani* from B.C.)

McArn, C. E.
J 26(8): 2215 (infection of English sole)

McBride, John Raymond
J 26(5): 1147 (sockeye salmon gland changes after gonadectomy)

(11): 2975 (sockeye salmon interrenal tissue hypertrophy & effect of gonadectomy)
S 1340 (dexamethasone in sockeye)

McCombie, Alan Milne
J 26(10): 2681 (fish shape & structure re selectivity of gillnets)

McCracken, Francis Derwood
T 86 (cod & haddock catches)
S 1316 (central Scotian Shelf haddock)

McCurdy, Howard Douglas
S 1285 (*Hexamita inflata* axenic cultivation from *Crassostrea virginica*)

McDermott, Lawrence Alfred
J 26(3): 629 (*Aeromonas salmonicida* phages)

McDonald, John George
J 26(2): 229 (sockeye fry survival)
S 1271 (sockeye population biology)

McFadden, Terence William
J 26(9): 2311 (disinfection of trout eggs)

McInerney, John Edward
J 26(8): 2061 (blackspotted stickleback reproductive behaviour)

McIntyre, John Demaris
J 26(12): 3252 (brook lamprey spawning behaviour)

McKeown, Brian Alfred
J 26(7): 1837 (sockeye ACTH & prolactin)

McLachlan, Jack
J 26(10): 2703 (sublittoral flora of Halifax Co., N.S.)

McLaren, Ian Alexander
J 26(6): 1485 (Ogac L. zooplankton)
(6): 1561 (primary production in Ogac L.)

McLeese, Donald Wilson
S 1276, 1277 (toxicity of kraft mill effluent to lobsters & salmon)
1278 (kraft pulp mill effluent for 2 aquatic animals)

McMullen, John Clarence
J 26(10): 2737 (delayed mating on reproduction of king crab)

McPhail, John Donald
J 26(12): 3183 (stickleback predation & evolution)

McQueen, Donald James
J 26(6): 1605 (*Cyclops bicuspidatus thomasi* predation)

Medcof, John Carl
J 26(5): 1121 (*Urosalpinx* distribution & importance)
T 101 (uses of ocean quahaugs)
S 1343 (migration of eels)

Medusae (*see also* Jellyfishes)
J 26(6): 1485 (*Anglantha digitale*, etc., ecology, Ogac L., Baffin Is.)

Megaptera novaeangliae (*see* Whale, humpback)

Melanogrammus aeglefinus (*see* Haddock)

Melicertum octocostatum (a hydromedusan)
J 26(6): 1535 (Ogac L., Baffin Is.)

Mercenaria mercenaria (*see* Quahaug)

Mercer, Malcolm Clarence
T 103 (otter-trawl survey N.S. to Cape Hatteras)
122 (mid-Atl. bight otter-trawl survey)
S 1327 (recent Cephalopoda of Canada)

Mercury
S 1274 (dispensing apparatus for)

Meristic characteristics (*see also* Morphology; Species, new; *also* Length; Size; Weight; *also* names of organisms)
J 26(6): 1467 (ranges for warty poacher)
(7): 1934 (re differentiating *Coregonus artedii* from *C. zenithicus*)
(9): 2431 (geographical variations in brook stickleback)
(9): 2537 (analysis, in N American Atl. mackerel coastal populations)

Merluccius
J 26(2): 421 (cranal osteology re other Gadidae genera)

Merluccius bilinearis (*see* Hake, silver)
productus (*see* Hake, Pacific)

Meromixis
J 26(7): 1763 (characteristics of 4 S B.C. lakes)

Mesh size of nets (*see also* Nets; Selectivity of fishing gear)
S 1345 (particulate matter retention by screens)

Mesocyclops edax (a copepod)
J 26(10): 2543 (vertical distribution & seasonal abundance, Parry Sound, Ont.)

Mesodinium rubrum (ciliate)
S 1294 (pigments)

Mesoplodon spp. (*see* Whales)

Mesoplodon stejnegeri (*see* Whale, Stejneger's beaked)

Messieh, Skoukry Naseef
J 26(7): 1889 (herring otolith nuclei)

T 139 (Gulf of St. Lawrence herring catch statistics)

Messtorff, Joachim
S 1279 (research vessels comparative fishing)

Metabolism (*see also* names of metabolic functions)
J 26(1): 115 (coho salmon & rainbow trout resistance to bacterial endotoxins)
(6): 1429 (re stream fishes ecology)
(7): 1813 (endogenous nitrogen secretion re bluegill protein maintenance level)
(9): 2362 (of young sockeye salmon)
S 1322 (of pyruvate & glyoxalate by Atl. salmon eggs)
A 118 (re sockeye salmon swimming speed)

Metabronema (nematodes)
S 1267 (taxonomy re *Oncorhynchus* parasitism)

Metacercariae (*see* Trematodes)

Metal ions (*see* Mineral content; Mineralization; Pollution; Toxicants; *also* names of elements)

Metamorphosis
J 26(4): 921 (*Phrixocephalus cincinnatus* parasitic copepod)
(11): 2823 (morphological & biochemical changes in steelhead trout parr-to-smolt)
A 123 (Nfld. salmon)

Metapenaeus dobsoni (*see* Shrimp (Arabian Sea))

Methionine (*see also* Acids, amino)
J 26(11): 2969 (free, in *Parapenaeus* Atl. shrimp)
S 1314 (reaction with malonaldehyde)

Mettrick, David Francis
J 26(10): 2269 (nutrition & chemical composition of *Syndesmis franciscana*, & taxonomy of *S. antillarum*)

Michigan, State of
J 26(11): 3077 (sea lamprey larvicides tests)

Micrococcus (*see also* Bacteria)
J 26(10): 2643 (population on vacuum- vs. air-packaged EDTA-treated fish fillets)
(10): 2659 (spp. ingested by oligochaetes in Toronto harbour sediments)

Microgadus tomcod (*see* Tomcod, Atlantic)

Micropterus dolomieui (*see* Bass, smallmouth)
salmoides (*see* Bass, largemouth)

Microsporidia (*see also* Sporozoa)
J 26(4): 725; (8): 2215 (infection of fishes)

Microstomus pacificus (*see* Sole, Dover)

Midshipman, northern (*Porichthys notatus*)
J 26(9): 2319 (parasites, B.C.)

Mighell, James LeRoy
J 26(10): 2765 (salmon & trout rapid cold-branding with liquid nitrogen)

Migration (*see also* Behaviour; Distribution; Homing; Marking; Spawning; Tagging)
J 26(1): 33 (lakeward, of young rainbow trout, upper Lardeau R., B.C.)
(2): 229 (Babine L. sockeye salmon fry, from natural vs. artificial stream rearing)
(2): 269 (NW Miramichi R., N.B., salmon to other Maritimes fishing areas)
(5): 1301 (American plaice, Nfld.)
(5): 1372 (theory of fish school size re navigation during)
(7): 1837 (re sockeye salmon pituitary activity)
(8): 2111, 2113 (olfactory responses of chinook & coho salmon)
CJG 16 (Nfld. herring stocks & coastal capelin)
T 105 (B.C. commercial groundfishes)
S 1343 (fishermen's reports on American eel freshwater & marine)
A 138 (queen crab)

Millemann, Raymond Eagan
J 26(9): 2339 (reproduction of shiner perch)

Mills, Eric Leonard
J 26(6): 1415 (marine zoology community concept)

Milt (*see* Semen; Testes)

Mineral content
J 26(8): 2030 (of beach-spawning Nfld. capelin)
(9): 2345 (re calculation of caloric content of zooplankton biomass)
(11): 2843 (of steelhead trout during parr-to-smolt transformation)
T 114 (Canadian Atl. herring meals)

Mineralization
J 26(1): 150; (5): 1347 (in culture media for calanoid copepods)
(5): 1133 (experimental, of seawater samples re phytoplankton growth)
S 1353 (of Gulf of St. Lawrence sediments)

Minnow, brassy (*Hybognathus kankinsoni*)
J 26(6): 1439 (distribution in Canadian Missouri R. headwaters)

Minnow, fathead (*Pimephales promelas*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(9): 2449 (chronic toxicity of copper to)

Minnow, flathead (*see* Chub, flathead)

Minnow, sheepshead (*Cyprinodon variegatus*)
J 26(2): 433 (blood morphology)

Minnow, silvery (*Hybognathus nuchalis*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Minnow, White Cloud Mountain (*Tanichthys albonubes*) (tropical cyprinid)
J 26(8): 2250 (laboratory host for cestode culture)

Miramichi River, N.B.
J 26(2): 269 (salmon migration to other Maritimes fishery areas, from NW)
T 91 (analysis of 1966 salmon smolt run in NW)

Mirounga angustirostris (*see* Seal, northern elephant)

Missouri River system
J 26(6): 1439 (fishes distribution in Canadian drainage)

Mite (*see* Acarina)

Model, tidal
J 26(9): 2477 (for Bay of Fundy)

Moisture content
J 26(8): 2030 (beach-spawning Nfld. capelin)
(11): 2843 (of steelhead trout during parr-to-smolt transformation)

Mollusca (*see also* subclassifications; *also* certain species names)
J 26(1): 55 Wash. coast benthic infauna standing crop)
(1): 145 (zinc content)
(4): 833 (parasitic, on yellow perch gills)
(5): 1273 (in Atl. cod & haddock feed)
(8): 2016 (partitioning community respiration in a lake sediment)
(12): 3101 (of Crecy L., N.B.)

Molt (*see* Moulting)

Molybdenum compounds
T 114 (content of Atl. & Pac. herring meals)

Monachus schauinslandi (*see* Seal, monk)

Monkfish (*Lophius americanus*)
J 26(3): 597(F) (retinal structure re activity, etc.)

Monochrysis lutheri (*see* Flagellata)

Monodon monoceros (*see* Narwhal)

Monogenea (*see also* Trematoda)
J 26(9): 2319 (list of species found in B.C. marine fishes)

Morley, Ronald Bruce
T 111 (salmon ova & milt)

Morphology; Morphometry (*see also* Cytology; Histology; Length; Meristic characteristics; Osteology; Size; Species, new; *also* names of organisms, organs, and tissues)
J 26(2): 311 (4 Lernaeopodidae parasitic copepods)
(2): 433 (blood, of 3 estuarine cyprinodontiform fishes)
(2): 469 (shortnose greeneye off SW N.S.)
(3): 543 (re polyteny of Ogac L., N.W.T., *Pseudocalanus*)
(3): 629 (*Aeromonas salmonicida* bacteriophages)
(4): 753 (metacercariae of 18 trematodes from S American fishes)
(4): 787 (3 new genera of hemiurid trematodes from Australian fishes)
(4): 793 (*Lepidophyllum cameroni*, new trematode species)
(4): 805 (helminths from Nfld. fishes)
(4): 821 (*Triaenophorous nodulosus* invasive stage in yellow perch)
(4): 849 (*Cystidicola* nematodes re genus revision)
(4): 865 (1 new *Pellucidhaptor* trematodes)
(4): 909 (*Pomphorhynchus laevis* acanthocephalan parasitization of Atl. salmon)
(4): 921 (*Phrixocephalus cincinnatus* parasitic copepod)
(4): 957 (2 trematode species (1 new) from S Calif. fishes)
(4): 997 (*Ergasilus* parasitic copepods re taxonomy)
(4): 1013 (*Caligus elongatus* parasitic copepod)
(4): 1037 (tetrarhynchian cestodes (1 new genus) from U.S. Atl. coast sharks)
(4): 1063 (*Diclidophora* trematodes)
(4): 1103 (nematodes from Australian birds)
(5): 1237 (*Acantholiparis caecus* new liparid species)
(5): 1383 (sockeye salmon shapes re gillnet selection)
(6): 1407 (*Tanypleurus alcicornis* parasitic copepod)
(6): 1451 (clam drill accessory boring organ)

(6): 1680 (rare deepsea cusk-eel, *Parabassogigas grandis*)
(8): 2247 (infectious pancreatic necrosis virus in rainbow trout pancreatic tissue)
(9): 2431 (brook stickleback: geographical variation)
(10): 2595 (*Acrocirrus* & *Macrochaeta* polychaetes)
(10): 2703 (variations with depth of Atl. seaweeds)
(11): 2785 (effects of copper sulphate toxicity to winter flounder)
(11): 2823 (of steelhead trout during parr-to-smolt transformation)
(11): 2987 (*Salmincola* parasitic copepods)
(11): 3043 (*Chondracanthus narium* parasitic copepod)
B 168 : 23, 52 (butter clam, re paralytic shellfish poisoning)
169 : 8 (Pac. oyster)
170 (& variation, of N American chironomids, including 33 new species)
T 136 (larval swordfish)
S 1263 (*Caligus longicaudatus* copepod)
1298 (*Salvelinema* nematodes buccal cavity)
1299 (*Salvelinema salmonicola* & *S. walkeri*)
1301, 1306 (type species of 2 new parasitic copepod genera)
1306, 1307 (copepods parasitic on Australian fishes)
1354 (rostellar hooks development in a cestode)

Morphometry (physical) (*see also* Physiography)
T 98 (Little Codroy R. & estuary, Nfld.)
130 (factors affecting Nfld. streams)

Mortality (*see also* Disease; Insecticides; Pesticides; Predation)
J 26(3): 479 (effects of size-selective, on growth, mortality, production, & yield estimates)
(3): 695 (mass, of brook trout & Atl. salmon in pesticide-polluted stream)
(3): 701 (mass of estuarine fauna due to abnormally low salinity, P.E.I.)
(5): 1205 (in exploited American plaice stock)
(12): 3133 (SW Nfld. cod: rates re landings, etc.)
B 169 : 113 (re Pac. oyster culture, B.C.)
T 108 (rates, rock sole, N Hecate Strait, B.C.)
S 1316 (rates, Scotian Shelf haddock)
1318 (W Nfld. cod stock)
A 135 (following *Oronectes virilis* crayfish moulting)

Mosquitofish (*Gambusia affinis*)
J 26(9): 2395 (resistance to 28 insecticides by resistant vs. nonresistant fish)

Moulting
J 26(4): 935 (codworm feeding behaviour during)
(8): 2101 (changes in lobster protein serum during)
(10): 2737 (of female king crab re mating & reproduction)
A 135 (endocrine levels effect on crayfish *Orconectes virilis* photoperiod of; also moulting mortality)
138 (queen crab)

Mounib, M. Said
S 1322 (pyruvate & glyoxylate metabolism by salmon eggs)
1342 (fish aminotransferases)

Mount, Donald Irvin
J 26(9): 2449 (toxicity of copper to minnows)

Mouse
J 26(5): 1378 (fibroblast cell spinner culture to detect water pollutants)

Mouth
S 1298 (*Salvelinema* nematodes buccal cavity)

Moxostoma anisurum (*see* Redhorse, silver)
macrolepidotum (*see* Redhorse, northern)
valenciennesi (*see* Mullet)

Mudminnow, western (*Novumbra hubbsi*)
J 26(12): 3183 (differential predation on red vs. black threespine stickleback)

Muir, Barry Sinclair
J 26(1): 165 (function of gill dimensions)

Mujib, Khawaja Abdul
J 26(2): 421 (osteology of *Brosme brosme*)

Mullet (*Moxostoma valenciennesi*) (redhorse)
B 151(F) (smoking)

Mummichog (*Fundulus heteroclitus*)
J 26(2): 433 (blood morphology)
(5): 1390 (distribution, Sable Is., N.S.)

Mundie, John Harold
S 1332 (diet of juvenile coho in streams)

Murchelano, Robert Adrian
J 26(10): 2760 (algal foods bacterial flora for rearing bivalve larvae)

Murray, Alan Roderick
J 26(6): 1694 (Atl. salmon muscle damage in gillnets)
T 98 (climatic & geomorphic aspects of Little Codroy R., Nfld.)
130 (factors affecting Nfld. streams)
A 123 (Nfld. Atl. salmon)

Muscle (*see also* Fillets; Flesh; Myosin; Protein; Quality)
J 26(2): 325 (indirect colour enhancement of trouts & pink salmon)
(5): 1368 (fluorescence of white sucker)
(6): 1597 (nucleotide degradation in frozen swordfish)
(6): 1694 (damage from nylon gillnetting of Atl. salmon)
(8): 2234 (colour of raw & cooked Atl. salmon, vs. canned Pac. salmons)
(8): 2237 (inhibitory agents for free fatty acid liberation from trout muscle during cold storage)
(10): 2621 (glycolytic & nucleotide changes in critical freezing zone of pre-rigor Atl. cod)
(10): 2633 (polymorphism of sablefish)
(10): 2727 (fatty acids reaction with Atl. cod muscle protein iced then frozen)
S 1349 (heat treatment isolation of tropomyosin from Atl. cod)
A 130 (review of nutritional value & preservation)

Musick, John Andrew
J 26(2): 473 (sculpin occurrence and spawning)

Muskellunge (*see* Maskinonge)

Mussel, bay (Atlantic) (*Mytilus edulis*) (blue mussel)
J 26(3): 701 (mortality from unusually low P.E.I. estuarine salinity)
(12): 3237 (feed in ration re growth analysis of European plaice)

Mussel, bay (Pacific) (*Mytilus edulis*)
J 26(1): 190; (8): 2245 (*Mytilicola orientalis* parasitic copepod in)
B 168 : 33 (toxicity tests, B.C.)

Mussel, blue (*see* Mussel, bay (Atlantic))

Mussel, sea (*Mytilus californianus*)
B 168 : 18 (re paralytic shellfish poisoning in B.C.)

Mustelicola woodsholei
J 26(4): 1037(F) (new genus & species of cestode)

Muth, Kenneth Maxwell
J 26(8): 2252 (broad whitefish age & growth)

Mya arenaria (*see* Clam, soft-shell)

Myctophidae (*see* Lanternfish)

Myctophum punctatum (*see* Lanternfish, spotted)

Myers, Betty June
J 26(4): 793 (nematodes from Malaysia)

Myoglobin
J 26(9): 2299 (effect on marine flesh lipids oxidation)

Myosin; Tropomyosin (*see also* Muscle)
S 1349 (tropomyosin isolation from Atl. cod muscle by heat treatment)

Myoxocephalus aeneus (*see* Grubby)
octodecemspinosus (*see* Sculpin, longhorn)
scorpius (*see* Sculpin, shorthorn)
polyacanthocephalus (*see* Sculpin, great)

Mytilicola orientalis (parasitic copepod)
J 26(1): 190; (8): 2245 (in Pac. coast oysters & bay mussels; fecundity)
B 169 : 157 (predator of Pac. oyster in B.C.)

Mytilus californianus (*see* Mussel, sea)
edulis (*see* Mussel, bay (Atlantic; Pacific))

Myxosporidia
J 26(4): 725 (infection of fishes)

N

Naevdal, Gunnar
J 26(5): 1397 (harp seals polymorphism)

Naobranchia (parasitic copepods)
S 1307 (*N. variabilis* on Australian fishes)

Narver, David Wells
J 26(2): 405 (stickleback phenotypic variation)
(5): 1363 (Owikeno L. productivity)
(10): 2754 (Babine R. steelhead trout age & size)

Narwhal (*Monodon monoceros*)
J 26(1): 143 (attacks by Greenland sharks)

Natarajan, A. V.
J 26(11): 3073 (derivation of average lengths of different age-groups of fishes)

Nautichthys oculofasciatus (*see* Sculpin, sailfin)

Nelson, Joseph Schieser
J 26(9): 2431 (variation in *Culaea inconstans*)

Nematoda (roundworms)
J 26(4): 793 (checklist of, from Sabah fishes, amphibians, & reptiles)
(4): 805 (of Nfld. fishes)

(4): 813 (*Contracaecum* larvae in pink salmon)
(4): 833 (in yellow perch, Bay of Quinte, Ont.)
(4): 849 (revision of *Cystidicola* genus)
(4): 935 (*Phocanema decipiens* moulting cycle feeding habits)
(4): 941 (*Philonema oncorhynchi* invasion route to sockeye swim bladder)
(4): 1103 (including 1 new species, from Australian gulls & terns)
(9): 2319 (list of species in B.C. marine fishes)
T 134 (as indicator species for distinguishing Atl. salmon stocks)
S 1267 (3 genera of Japanese, re *Oncorhynchus* parasitization)
1298 (*Salvelinema* buccal structure)
1299 (Cystidicolinae parasites of Pac. salmons)
1299, 1300 (*Salvelinema walkeri* parasitic in coho salmon swim bladder)

Nemichthys scolopaceus (*see* Eel, Atlantic snipe)

Neohaustorius biarticulatus (sand-burrowing amphipod)
J 26(2): 361 (ecology, life history, behaviour)
(9): 2283 (physiological tolerances & behaviour responses to 5 environmental factors)

Nervous system
S 1324 (DDT sublethal effect on brook trout)

Nessorhamphus ingolfianus (*see* Eel, duckbill oceanic)

Nets (*see also* Selectivity of fishing gear)
J 26(6): 1694 (Atl. salmon muscle damage from nylon gill)
(8): 2240 (otter surface sampler for neuston)
(10): 2681 (selectivity of gillnets re fish shape & structure)
S 1281 (field tests for synthetic fibres used in)
A 129 (synthetic, used for fishing gear)

New Brunswick (*see also* other fisheries, also localities)
A 138 (queen crab)

Newfoundland (*see also* Labrador)
J 26(4): 805 (fish parasites)
(6): 1585 (differences in 2 landlocked Atl. salmon populations)
(6): 1689 (grubby distribution)
(8): 2027, 2037 (chemical composition of beach-spawning capelin, re fishery potential)
(12): 3133 (cod fishery & biology off SW coast)
(12): 3217 (bacteriology of commercial cod & flounder fillets from fish variously handled at sea)
CJG 16 (fishery investigations & landings, 1968)
T 94–97 (herring sampling data & summary tabulations, 1964–65 to 1967–68)
130 (factors affecting productivity of many streams)
S 1283 (herring fishery re its resource)
1367 (salmon distribution & characteristics from banks & deeps off)
1368 (biology & fishery of stock off W)
A 123 (Atl. salmon, review of research, biology, commercial, & sport fishery)
137 (cod research)
138 (queen crab exploratory fishing)

Niacin (*see* Vitamin B group)

Nitrate
J 26(5): 1133 (re marine phytoplankton growth)
(6): 1561 (re primary production, Ogac L., Baffin Is.)
(12): 3101 (in a lake after several fertilizations)
T 120 (in Bedford Basin waters, N.S.)
S 1273 (partial molal volume of sodium, potassium, magnesium, and calcium in sea water)
1341 (re eutrophication of inlet extension of Victoria harbour, B.C.)
1355 (distribution in NE Pac. Ocean)

Nitrite
T 120 (in Bedford Basin waters, N.S.)
S 1341 (re eutrophication of inlet extension of Victoria harbour, B.C.)

Nitrilotriacetic acid
S 1291 (chelating antipollutant for protecting fish from copper & zinc in waters)

Nitrogen compounds (*see also* types of)
J 27(7): 1813 (excretion of endogenous, re bluegill protein maintenance level)
(8): 2030 (nonprotein content, of Nfld. capelin)

Noise (*see* Sound, reactions to)

Nomenclature (*see also* Taxonomy)
J 26(3): 687 (new *Anonyx* synonymy)
(9): 2431 (brook stickleback)
B 170 (N American Chironomidae, & synonymy)

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S 1293 (application to change *Caligus appendiculatus* to *C. lacustris*)

Nonwetting surface
S 1275 (silicone for producing, on glass apparatus)

Norris, David Otto
J 26(7): 1801 (rainbow trout on pellet diets)

Norris, James Scott
J 26(7): 1801 (rainbow trout on pellet diets)

Northcote, Thomas Gordon
J 26(1): 33 (rainbow trout migration)
(7): 1763 (meromictic lakes changes)

Northwest Territories, Canada (*see* Arctic, Canadian; *also* names of places, islands, bodies of water)

Nota, Dirk Johannes Gregorius
S 1353 (mineral dispersal patterns)

Notolepis rissoi krøyeri (*see* Barracudina, white)

Notolynchus valdiviae (a lanternfish)
J 26(10): 2691 (first Canadian record)

Notoscopelus krøyeri (*see* Lanternfish, Krøyer's)
resplendens (*see* Lanternfish, patchwork)

Notropis atherinoides (*see* Shiner, emerald)
blennuis (*see* Shiner, river)
hudsonius (*see* Shiner, spottail)

Noturus flavus (*see* Stonecat)

Nova Scotia (*see also* other fisheries; *also* localities)
A 138 (queen crab)

Nova Scotia Banks
J 26(5): 1273 (comparison of cod & haddock feed)
(10): 2691 (mesopelagic & other fishes)

Novumbra hubbsi (*see* Mudminnow, western)

Nowlan, Sandra Simpson
J 26(10): 2621 (cod muscle changes during freezing)

Nucleotides (*see also* Acids, nucleic)
J 26(3): 704 (& related compounds in canned shrimp)
(5): 1368 (fluorescence of white sucker muscle)
(6): 1597 (degradation in frozen swordfish muscle)
(10): 2621 (changes in critical freezing zone of Atl. cod muscle)

Nursall, John Ralph
J 26(6): 1672 (spottail shiners & yellow perch aggregations)
(8): 2260 (*Triaenophorus crassus* in arctic lampreys)

Nutrients, aquatic (*see also* Oceanography; Productivity, primary)
T 110 (nitrate, nitrite, phosphorus, silicate, carbon, etc., Strait of Georgia, 1965–67)
S 1355 (nitrate distribution in NE Pac. Ocean)

Nutrition (*see also* Culture; Feed)
J 26(10): 2659 (resources of 3 oligochaetes in Toronto harbour sediments)
(10): 2669 (of turbellarian *Syndesmis franciscanus*)

Nutrition value (*see also* Composition, chemical; Productivity, primary)
J 26(3): 557 (of particulate vs. filter-feeding habits of northern anchovy)
(11): 2969 (*Parapenaeus* Atl. shrimps)
B 169 : 137 (Pac. oyster)
T 114 (Canadian Atl. herring meals)
A 124 : 48; 125 (fish protein concentrates)
130 (review of fish muscle, & preservation)

Nyman, Olof Lennart
J 26(9): 2532 (serum esterases in freshwater fishes)

O

Occa verrucosa (*see* Poacher, warty)

Ocean (*see* Hydrography; Oceanography; *also* names of oceans)

Oceanography, Atl. coast (*see also* Hydrography)
J 26(9): 2477; (11): 2775 (tidal barriers effect on Bay of Fundy M_2 tide re tidal power project)
(10): 2746 (1968 water temperature conditions in & off Gulf of Maine)
(11): 2887 (theory of tidal energy exploitation re Bay of Fundy)
(12): 3248 (re swordfish spawning)
T 115 (physical, of Margaree & Chéticamp R., N.S.)
120 (Bedford Basin, N.S.)
S 1280 (temperatures & salinities, St. John's–Flemish Cap Section)
A 134 (function of Dartmouth Marine Ecology Laboratory, N.S.)

Oceanography, general
J 26(7): 1948 (2 useful devices for vertical plankton & water sampling)
(8): 2223 (rate of storm growth effect on subsequent surge elevations)
S 1273 (partial molal volumes of 16 salts in)

Oceanography, North Pacific Ocean (*see also* Oceanography, Pacific Coast)
T 126 (transport computations, 1968)

127 (transport charts, 1968)
128 (Ekman transport divergence computations, 1946–68)
S 1295 (critical indices of primary & secondary production)
1355 (nitrate distribution in NE)

Oceanography, Pacific Coast
J 26(12): 3165 (biological, Strait of Georgia)
B 171 : 2 (re B.C. marine mammals)
T 99 (water movements over Saanich Inlet sill, B.C.)
106 (time distribution of serial data from Ocean Weather Station P program)
110 (biological, observations summary for Strait of Georgia, 1965–68)
S 1295 (critical indices of primary & secondary production)
1341 (eutrophication of inlet extension of Victoria harbour, B.C.)

Ocenebra japonica (*see* Oyster drill, Japanese)

O'Connell, Charles Patrick
J 26(3): 557 (anchovy feeding)

Octopuses
S 1327 (Canadian with synopsis)

Odense, Paul Holger
S 1349 (isolation of tropomyosin)

Odonata
J 26(8): 2016 (partitioning community respiration in a lake sediment)
(12): 3101 (list of Crecy L., N.B.)
T 130 : 225 (of Nfld. streams)

Odours, and reactions to
J 26(3): 583 (Atl. cod reactions towards various feeds & extracts)
(5): 1243 (homing of anosmic vs. blind-anosmic and normal cutthroat trout)
(8): 2111, 2123 (chinook & coho salmon discrimination of natural waters)
J 26(9): 2299 (developed during oxidative rancidity of marine flesh lipids)
T 101 (of experimentally canned ocean quahaug)

Ogac Lake (semi-tidal), Baffin Is., N.W.T.
J 26(3): 543 (*Pseudocalanus* polyteny & size variation)
(6): 1485 (zooplankton population & production ecology)
(6): 1561 (primary production & nutrients)

O'Halloran, Mary-Jane
J 26(7): 1823 (sodium transport re 1α-hydroxycorticosterone)

Oils and fats, aquatic animal (*see also* Acids, fatty; Condition; Lipids; Phospholipids; Triglycerides)
J26 (7): 1919, 1923 (extraction from Atl. herring for preparing fish protein concentrate)
(8): 2077 (role in Atl. & Pac. herring buoyancy)
(8): 2093 (role in Atl. salmon parr & smolt buoyancy)
(9): 2363 (content of young sockeye salmon re feed conversion efficiency)
T 79 (Atl. herring fat contents, & content re season & herring length)
S 1350 (extraction from Atl. herring material for fish protein concentrate; also composition of)
A 124, 125 (extraction & residual, fish protein concentrates)

Oithona similis (a copepod)
J 26(6): 1485 (ecology, etc., Ogac L., Baffin Is.)

Oligochaeta
J 26(8): 2016 (partitioning community respiration in a lake sediment)
(10): 2581 (bottom corer for sampling tubificid)
(10): 2659 (nutritional resources of 3 tubificid species in Toronto harbour sediments)

Oligocottus maculosus (*see* Sculpin, tidepool)

Olfactory perception and response (*see* Odours)

Oliver, Donald Raymond
T 124 (Nearctic Chironomidae classification)

Ommatokoita elongata (parasitic copepod)
J 26(1): 143 (on Greenland shark cornea)

Oncorhynchus gorbuscha (*see* Salmon, pink)
keta (*see* Salmon, chum)
kisutch (*see* Salmon, coho)
masou (*see* Salmon, masu)
nerka (*see* Salmon, sockeye; *also* Kokanee)
rhodurus (*see* Salmon, biwa)
tshawytscha (*see* Salmon, chinook)

Ontario, Lake (*see also* Great Lakes)
J 26(4): 833 (yellow perch parasites, Bay of Quinte)
(8): 2135 (crustacean plankton horizontal distribution & composition)

Oocyte (*see* Eggs; Ovary; Reproduction)

Opaleye (*Girella nigricans*)
J 26(4): 957(F) (*Opegaster cameroni* new trematode species from)

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Opegaster cameroni (trematode)
J 26(4): 957(F) (new species from S Calif. fishes)

Ophiodon elongatus (*see* Lingcod)

Ophiuroidea (*see also* Starfish)
J 26(7): 1727 (synopsis & key to Wash. & S B.C.)

Orcinus orca (*see* Whale, killer)

Orconectes virilis (*see* Crayfish)

Organophosphates (*see* Phosphates; Phospholipids; Phosphorus compounds)

Orientation (*see* Buoyancy; Distribution; Homing; Migration)

Orr, Thomas Samuel Campbell
J 26(4): 741 (*Schistocephalus solidus*, a tapeworm)
(8): 2250 (*Ligula intestinalis* life cycle)

Orthocladiinae
B 170 (descriptions, morphology, taxonomy, distribution, etc., of 47 species)
T 124 (classification of Nearctic)

Oshima, Kiyoshi
J 26(8): 2111 (salmon olfactory discrimination)
(8): 2123 (salmon olfactory responses)

Osmerus mordax (*see* Smelt, American)

Osmoregulation (*see* Salinity, reactions to)

Osteology (*see also* Skeleton)
J 26(1): 175 (re distinguishing northern pike vs. maskinonge fillets or remains)
(2): 421 (cranial, of cusk re other Gadidae genera)
B 171 (identification of B.C. marine mammals from skull remains)

Ostrea lurida (*see* Oyster, Olympic)

Otaria byronia (*see* Sea lion)

Otodistomum veliporum (trematode)
J 26(4): 957(F) (description)

Otoliths (for fish age determination (*see also* Age)
J 26(7): 1889 (nuclei similarity in spring- & autumn-spawning Atl. herring)
(12): 3133 (growth in cod off SW Nfld.)
T 108 (rock sole, B.C.)
109 (yellowfin sole, B.C.)
S 1318 (W Nfld. cod stock)

Ouananiche (*see* Salmon, Atlantic landlocked)

Ova (*see* Eggs)

Ovary (*see also* Eggs)
J 26(2): 461 (temperature, *p*H, & virus effects on rainbow trout cells in vitro)
(7): 1789 (gonadectomy effects on sockeye salmon cortisol secretion rate)
(7): 1943 (anatomy re winter flounder oocyte maturation)
(9): 2521 (re lake whitefish hermaphroditism)
(11): 2975 (re interrenal tissue hypertrophy in sexually maturing sockeye salmon)
(12): 3242 (fibrous & cystic lesions in, of aged Atl. cod)
S 1292 (goldfish ovulation restored by salmon pituitary extract)

Overbeeke, Abraham Pieter van
J 26(5): 1147 (sockeye gland changes after gonadectomy)
(7): 1837 (sockeye ACTH & prolactin)
(11): 2975 (sockeye interrenal tissue hypertrophy & effect of gonadectomy)

Owikeno Lake, B.C.
J 26(5): 1363 (primary productivity re sockeye salmon production)

Oxygen, dissolved (*see also* Hydrography; Limnology; Oceanography; Respiration)
J 26(1): 63 (hypoxial stress in coho salmon egg & fry; effects on fry competitiveness)
(6): 1561 (re primary production, Ogac L., Baffin Is.)
(9): 2283 (tolerance of 5 haustoriid amphipod species)
(9): 2493 (re lead effect on brook trout growth)
(10): 2746 (1968, and in off Gulf of Maine)
(11): 2807 (re salinity & swimming speed of *Tilapia nilotica*)
T 120 (Bedford Basin, N.S.)
130 (availability in Nfld. streams re industrial pollution)

Oyster, Atlantic (*Crassostrea virginica*)
J 26(1): 171 (Malpeque Bay, P.E.I., physiographic changes re possible effects on production)
(3): 707 (2 modified stains for tissue pathology)
(5): 1121 (distribution & industrial importance of parasitic drill on Canadian Atl. coast)
(10): 2760 (bacterial flora of some algal feeds for rearing larvae)
B 169 : 6 (in B.C.)
CJG 16 : 24 (results of transplantation from P.E.I. to Nfld.)
S 1285 (axenic culture of *Hexamita inflata* from, re possible relationship to Malpeque disease)

Oyster, olympic (*Ostrea lurida*)
B 169 : 4 (localities found in, B.C.)

Oyster, Pacific (*Crassostrea gigas*)
J 26(1): 190; (8): 2245 (*Mytilicola orientalis* parasitic copepod in)
B 168 : 33; 169: 151 (paralytic shellfish poison tests, B.C.)
169 (culture, harvesting, processing, marketing, etc. in B.C.)

Oyster drill, Atlantic (*Polinices heros*)
S 1315 (sexual dimorphism)

Oyster drill, eastern (*Urosalpinx cinerea*)
J 26(5): 1121 (distribution & industrial importance, Canadian Atl. coast)
B 169 : 159 (introduced pest to Pac. oyster culture, B.C.)

Oyster drill, Japanese (*Ocenebra japonica*)
B 169 : 159 (introduced pest to Pac. oyster culture, B.C.)

P

Pacific Fisheries Marine Commission
S 1319 (results of English sole tagging, B.C.)

Pacific Ocean (*see also* Hydrography; Oceanography)
J 26(2): 199 (plankton primary production in NE)
(5): 1133 (experimental nutrient enrichment of seawater samples from tropical areas re phytoplankton growth)
(8): 1985 (evaluation of exploratory fishing methods in NE; stock size & yield forecasts)

Packaging
J 26(10): 2651 (vacuum vs. air, re EDTA preservative action on fish fillets)
B 151(F) (freshwater fish products)
169 : 108 (Pac. oyster, B.C.)

Page, Orville Thomas
J 26(1): 47 (DDT degradation by salmon)

Pagophilus groenlandicus (*see* Seal, harp)

Pagurus (sp.?) (*see* Crab, hermit)

Paim, Uno
J 26(1): 47 (DDT degradation by salmon)

Paints, antifouling
T 119 (for ships' hulls)

Pancreas
J 26(6): 145 (detection of brook trout carriers of infectious pancreatic necrosis virus)
(8): 2247 (morphology of infectious pancreatic necrosis virus in rainbow trout pancreatic tissue)
(9): 2511 (clinical & immune response of trouts to inoculation with pancreatic necrosis live virus)
(12): 3259 (incidence of necrosis virus in trouts & salmon in Atl. hatcheries)

Pandalus montagui (*see* Shrimp, striped pink)
platceros (*see* Prawn)

Pantosteus platyrhynchus (*see* Sucker, northern mountain)

Pantothenic acid (*see* Vitamin B group)

Parabassogagus grandis (*see* Cusk-eel (a deep-sea))

Parahaustorius longimerus (sand-burrowing amphipod)
J 26(5): 1321 (ecology & life cycle)
(9): 2283 (tolerances & behaviour)

Paralichthys californicus (*see* Halibut, California)

Paralithodes camtschatica (*see* Crab, king)

Paralytic shellfish poisoning
B 168, 169: 151 (cause, nature, precautions, control, case histories, etc. in B.C.)

Parapenaeus spp. (Atl. shrimps)
J 26(11): 2969 (chemical composition & nutritive value)

Parasites; Parasitization (*see also* Disease)
J 26(1): 143 (*Ommatokoita elongata* copepod on Greenland shark eye)
(1): 190; (8): 2245 (*Mytilicola orientalis* copepod in Pac. coast oyster & mussel)
(2): 311 (4 Lernaeopodidae copepods on Nfld. & W Greenland fishes)
(4): Complete issue (of aquatic organisms) (For more detailed references, *see* the page entries for issue J 26(4) under the headings for the following types of parasites: Acarina; Acanthocephala; Amphipoda; Cestoda; Copepoda; Hirudinea; Mollusca; Nematoda; Protozoa; Sporozoa; Trematoda)
(5): 1121 (oyster drill, Canadian Atl. coast)
(9): 2319 (of various B.C. marine fishes)
(11): 2987 (revision of *Salmincola* copepod genus)
B 169 : 154 (& pests re Pac. oyster culture, B.C.)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

T 134 (of Atl. salmon as biological indicators)
S 1267 (nematodes in *Oncorhynchus* salmons)
1269 (detection in lake whitefish by ultrasound)
1287 (digenetic trematode in Atl. argentine stomach)
1298–1300 (nematodes in Pac. salmons swim bladder)
1301, 1306 (new genera & species of copepod)
1302 (indicator species for high seas chum salmon origin)
1317 (of salmon off Nfld.)

Paricterotaenia paradoxa (cestode)
S 1354 (rostellar hooks development)

Parker, Robert Ray
J 26(4): 1013 (*Caligus elongatus* validity)
S 1263 (*Caligus longicaudatus* Brady 1899)
1293 (*Caligus appendiculatus* request for suppression)

Parophrys vetulus (*see* Sole, English)

Parr (*see* Salmon, Atlantic; *also* species of Pacific salmons; *also* species of trouts)

Parry Sound, Georgian Bay, Lake Huron, Ont.
J 26(10): 2543 (life cycle, seasonal abundance, & vertical distribution of various planktonic copepods)

Parsons, Leon Scott
T 97 (Nfld. herring sampling data 1967–68)

Parsons, Timothy Richard
S 1294 (*Mesodinium rubrum* ciliate pigments)
1295 (ocean surveys discussion of critical indices)
1303 (marine sediment decomposition)
1326 (allochthonous bacteria & organic materials)
1355 (NE Pac. Ocean nitrate)

Particulate matter (*see* Matter, particulate)

Pasiphaea multidentata (*see* Shrimp, glass)

Patalas, Kazimierz
J 26(8): 2135 (L. Ont. crustacean plankton)

Paterson, Colin Garth
J 26(7): 1934 (occurrence of *Coregonus artedii* & *C. zenithicus*)

Paterson, William Douglas
J 26(3): 629 (*Aeromonas salmonicida* phages)

Pathogens (*see* Bacteria; Disease)

Pathology; Pathological conditions (*see also* Disease)
J 26(3): 707 (two modified stains for oyster tissues)
(8): 2215 (of microsporidial infection of English sole)
(9): 2425 (progressive changes in carp ventral aorta)
(11): 2785 (of copper sulphate toxicity to winter flounder)
(12): 3242 (fibrous & cystic lesions in ovaries of aged Atl. cod)

Patrick, Karl
J 26(11): 3055 (tetrachloro-*o*-benzoquinone toxic to young salmon)

Pattie, Bradley Herren
J 26(5): 1371 (range of ocean whitefish & California halibut)

Pauley, Gilbert Buckhannan
J 26(3): 707 (stains for use in oyster pathology)

Pearcy, William Gordon
J 26(8): 2211 (shelf rockfish feeding)

Pearls
B 169 : 11 (from Pac. oyster valueless)

Pearlsides, Müller's (*Maurolicus muelleri*)
J 26(10): 2691 (range in Canadian Atl. waters; diurnal depth distribution)

Pearlstone, Paul Stephen Maurice
J 26(9): 2413 (survival of planted lake trout)

Pecten (*Patinopecten*) *caurinus* (*see* Scallop, weathervane)

Pelecypods (*see also* Bivalves; *also* subclassifications)
J 26(3): 701 (severe mortalities due to unusually low P.E.I. estuarine salinity)
(4): 833 (parasitic on yellow perch gills)
(12): 3101 (of Crecy L., N.B.)

Peloscolax multisetosus (tubificid oligochaete)
J 26(10): 2659 (nutritional resources in Toronto harbour sediments)

Pelroy, Gretchen Ann
J 26(10): 2651 (EDTA on spoilage of petrale sole & ocean perch fillets)

Pen (of squid)
J 26(6): 1676 (length of, re other *Lolliguncula brevis* measurements)

Pendrell Sound, B.C.
B 169 : 69 (re Pac. oyster breeding)
T 110 (biological oceanography observations summary 1965–68)

Pequegnat, John Eugene
J 26(1): 145 (marine organisms zinc requirements)

Perca (*fluviatilis*) *flavescens* (*see* Perch, American yellow)

Perch, American yellow (*Perca* (*fluviatilis*) *flavescens*)
J 26(2): 325 (S Atl. distribution)
(4): 821 (*Triaenophorus nodulosus* infection dynamics, Heming L., Man.)
(4): 833 (*T. nodulosus* & other parasites, Bay of Quinte, Ont.)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(6): 1647 (larvae sustained swimming ability)
(6): 1672 (aggregations with spottail shiners; predators)
(10): 2681 (shape & structure re selectivity of gillnets)

Perch, kelp (*Brachyisteus frenatus*)
J 26(9): 2319 (parasites, B.C.)

Perch, Pacific Ocean (*Sebastodes alutus*)
J 26(8): 1985 (stock size & yield forecast, N Pac. Ocean)
(9): 2319 (parasites, B.C.)
(10): 2651 (EDTA effect on fillet spoilage characteristics)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 113 (catch rates, size composition, W coast Vancouver Is.
117, 131 (B.C. commercial trawl landings, 1968)
132 (data from experimental groundfish cruise, B.C.)

Perch, pile (*Rhacochilus vacca*)
J 26(9): 2319 (parasites, B.C.)

Perch, shiner (*Cymatogaster aggregata*)
J 26(9): 2319 (parasites, B.C.)
(9): 2339 (female age & size re embryo number & size)

Percopsis omiscomaycus (*see* Troutperch)

Pereyra, Walter Thomas
J 26(8): 1985 (exploratory fishing methods)
(8): 2211 (shelf rockfish feeding)

Periwinkle, rough (*Littorina saxitilis*)
J 26(3): 701 (resistance to abnormally low estuarine salinity)

Peru
J 26(4): 713 (*Diphyllobothrium* & other parasites in fish, birds, marine mammals, & man)

Pesticides (*see also* Herbicides; Insecticides; Pollution; Toxicants)
J 26(3): 695 (mass mortalities & behaviour of brook trout & young Atl. salmon re nabam & endrin)
(5): 1378 (water pollution detection by spinner culture of mouse fibroblast cells)
B 169 : 163 (re Pac. oyster culture, B.C.)

Peter, Richard Ector
J 26(2): 325 (S Alta. fishes)

Peterson, Margaret Raymonde
S 1324 (DDT effects on brook trout)

Peterson, Richard Harry
J 26(1): 93 (Atl. salmon activity)

Petromyson marinus (*see* Lamprey, sea)

*p*H (*see also* Limnology; Oceanography)
J 26(2): 413 (Atl. salmon seminal components)
(2): 461 (limits for in vitro culture of rainbow trout ovary cells)

Phaeodactylum tricornutum (a phytoplankter)
J 26(6): 1625 (chlorophylls extraction procedure; correction on J 26(8): 2264)

Phaeophyceae (*see also* Seaweeds)
J 26(10): 2703 (of Halifax Co., N.S.)

Phenotypes
J 26(1): 15 (of sockeye salmon blood serum lactate dehydrogenase)
(2): 405 (4 threespine stickleback variations, Alaska)
(2): 456 (upper lethal temperature uniformity in phenotypic Great Lakes rainbow trout)
(9): 2351 (of Pac. halibut blood serum transferrins)
(9): 2532 (of white bream & ruff blood serum esterases)
(10): 2633 (sablefish muscle protein polymorphism)
(12): 3268 (frequencies of transferrin, in Pac. hake serum)

Phillips, Gary Lee
J 26(11): 2881 (hematological studies of 2 buffalofishes)

Phillips, Robert Wilson
J 26(1): 133 (estimating salmonid survival)

Philonema oncorhynchi (nematode)
J 26(4): 941 (invasion route to sockeye salmon swim bladder)
(9): 1329 (in B.C. coho & chinook salmon)

Phinney, Duane Earl
J 26(6): 1619 (coho marking & finclipping)

Phoca vitulina richardi (*see* Seal, Pacific harbour)

Phocaena phocaena (*see* Porpoise, Pacific harbour)

Phocanema decipiens (*see* Codworm)

Phocoenoides dalli (*see* Porpoise, Dall)

Pholis laeta (*see* Gunnel, crescent)
ornata (*see* Gunnel, saddleback)

Phosphates (*see also* Limnology; Nucleotides; Oceanography)
J 26(5): 1133 (re marine phytoplankton growth)
(6): 1561 (re primary production, Ogac L., Baffin Is.)
(8): 2193 (organophosphate insecticide effect on rainbow trout larvae)
(9): 2395 (organophosphate insecticides effect on resistant vs. nonresistant mosquitofish)
(9): 2517 (glyceraldehyde-3-phosphate dehydrogenase activity re temperature)
(12): 3175 (alpha-glycerophosphate dehydrogenase activity as new index of iced-storage age of fresh-gutted fish)
(12): 3101 (concentrations in a lake after several fertilizations)
(12): 3209 (effect of feeding & DDT on hepatic glucose 6-phosphate dehydrogenase in fish)
T 120 (phosphate in Bedford Basin waters, N.S.)
S 1341 (re eutrophication of inlet extension of Victoria harbour, B.C.)

Phospholipids
J 26(6): 1557 (source of free fatty acids in Atl. herring oils)
(8): 2037 (of capelin lipids)
(9): 2237 (re free fatty acid formation in refrigerated fish muscle)
S 1272 (of giant scallop, also in vivo incorporation of radioactive bases into)
1286 (content in eulachon bils lipids)
1346 (biosynthesis by lobster)

Phosphorus compounds (*see also* Nucleosides; Phosphates; Phospholipids)
J 26(11): 2969 (content of *Parapenaeus* Atl. shrimp)
(12): 3101 (organic, in a lake after several fertilizations)
T 114 (content of Atl. & Pac. herring meals)

Photography, underwater
T 102 (from cubmarine)
A 136 (from cubmarine)

Photoperiod effects (*see* Diel effects; Illumination; Light, reactions to)

Photosynthesis (*see also* Algae; Chlorophylls; Diel habits; Pigments; Plankton; Phytoplankton, Productivity, primary)
J 26(2): 463 (efficiency of phytoplankton re light intensity)
(8): 2003 (in epibenthic algae, Marion L., B.C.)
(11): 2959 (salinity & illumination effects on chlorophyll & carotenoids production in a flagellate)

Phototropism (*see* Light, reactions to; Scototaxis)

Phrixocephalus cincinnatus (parasitic copepod)
J 26(4): 921 (morphology, metamorphosis, host–parasite relations)

Phycodrys rubens (seaweed)
J 26(10): 2703 (photo)

Phyllobothrium (cestodes)
J 26(4): 805 (in Nfld. fishes)
(4): 813 (of early sea life pink salmon)
(9): 2319 (in B.C. marine fishes)
T 103 (infection in short-finned squid)

Physeter catodon (*see* Whale, sperm)

Physiography (*see also* Geomorphology; Morphometry (physical))
J 26(1): 171 (changes in Malpeque Bay, P.E.I., re oyster culture)

Physiology (*see also* aspects of)
J 26(3): 639 (American eel corpuscles of Stannius re renal)
(7): 1847 (aortic catheterization effects on brook trout)
(9): 2283 (tolerances of 5 haustoriid amphipod species to 5 environmental factors)
S 1344 (*Gaffkya homari* effects on lobster)
A 138 (queen crab)

Phytanic acid
S 1266 (re Refsum's disease)

Phytoplankton (*see also* Algae; Chlorophylls; Feed; Plankton; Production, primary)
J 26(2): 199 (production re zooplankton in NE Pac. Ocean; corrections on J 26(8): 2264)
(2): 463 (light intensity diel periodicity re photosynthesis efficiency)
(5): 1133 (re experimental nutrient enrichment of sea water)
(6): 1625 (chlorophyll extraction from 5 marine species; correction on J 26(8): 2264)
(12): 3101 (changes after several fertilizations of a lake)
T 110 (seasonal distribution of 3 species, Strait of Georgia, 1965–67)
120 (Bedford Basin, N.S.)

Pickerel, redfin (*Esox americanus*)
J 26(4): 849 (*Cystidicola* nematode in swim bladder)

Pickerel, yellow (*see* Walleye)

Pictou, N.S.
J 26(7): 1931 (lobster larvae unaffected by bleached kraft mill effluent)

Pienaar, Leon Visser
J 26(1): 123 (weight–length regression model)
T 92 (A 1130 FORTRAN version of FRG 708)
112 (multiple discriminant analysis (FORTRAN 1130))

Pigments; Pigmentation (*see also* Chlorophylls; Discoloration; Stains)
J 26(2): 357 (indirect pigmentation of trouts & pink salmon flesh by canthaxanthin in feed)
(5): 1185 (in coho salmon fry belly skin)
(6): 1619 (fluorescent, for marking coho salmon fry)
(6): 1667 (fluorescent, for separating invertebrates from sediments)
(8): 2234 (carotenoid, re colour of raw & cooked Atl. salmon flesh vs. canned Pac. salmons flesh)
(11): 2959 (salinity-induced changes in *Monochrysis lutheri* flagellate)
(12): 3183 (origin, etc. of red- vs. black-skinned threespine stickleback)
(12): 3262 (re Pac. spiny lumpsucker sexual dimorphism)
S 1294 (origin of ciliate *Mesodinium rubrum*)
1309 (colour sorting of raw sockeye & coho salmon flesh re subsequent colour of canned)
A 124 (colour reflectance of fish protein concentrates)

Pike, Gordon Chesley
B 171 (B.C. marine mammals)
A 122 (N Pac. whaling — end of era)

Pike, northern (*Esox lucius*)
J 26(1): 175 (distinguishing fillets or remains from those of maskinonge)
(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(7): 1927 (purine sources of skin silvering, swimbladder, & eye silvery layer)
(12): 3266 (diel activity, judged by gillnet catchability)
B 151(F) (smoking)
T 129 (used as example in computer programming for statistical analysis of length-frequency data)

Pilchard (*see* Sardine, Pacific)

Pimephales promelas (*see* Minnow, fathead)

Pinder, Lesley Jeanette
J 26(8): 2093 (Atl. salmon buoyancy)

Pinhorn, Allenby Thomas
J 26(12): 3133 (SW Nfld. coast Atl. cod)

Pinnipedia (*see also* Sea lion; Seal)
B 171 (of B.C.)

Pinsent, Morley Edward
J 26(6): 1672 (spottail shiners & yellow perch aggregations)

Pipefish, bay (*Syngnathus griseolineatus*)
J 26(9): 2319 (parasites, B.C.)

Pippy, John Herbert Charles
J 26(4): 909 (*Pomphorhynchus laevis* in *Salmo salar*)
(9): 2535 (kidney disease in Atl. salmon)
T 134 (1966–68 investigations re parasites as biological tags in Atl. salmon)

Pisaster brevispinus (*see* Starfish, pink)
ochraceus (*see* Starfish, ochre)

Piscicides (*see also* Pollution; Toxicants)
J 26(11): 3077 (2 sea lamprey larvicides evaluation in Michigan waters)

Pituitary
J 26(5): 1147 (cytology of sockeye salmon after gonadectomy)
(7): 1837 (immunohistochemical localization of ACTH & prolactin in sockeye salmon)
(11): 2975 (re hypertrophy of sexually maturing sockeye salmon interrenal tissue)
S 1292, 1336 (gonadotropin of chinook salmon induces spermatogenesis & ovulation in hypophysectomized goldfish)
1340 (stressed maturing sockeye salmon interrenal activity suppression by dexamethasone corticosteroid injection)

Pitt, Thomas Kenton
J 26(5): 1301 (American plaice migration)

Placopecten magellanicus (*see* Scallop, giant)

Plaice, American (*Hippoglossoides platessoides*)
J 26(5): 1205 (size changes, mortality, & equilibrium yields in an exploited stock)
(5): 1301 (tagging & migration, Nfld.)
(9): 2299 (promoters & inhibitors of muscle lipids oxidation)
(12): 3217 (bacteriology of commercial fillets from fish iced at sea & thawed in water)

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CJG 16 (research vessel catches, 1958–66. & commercial landings, 1953–68, Nfld.)
T 103 (in experimental otter-trawling, 1967)
A 119 (ICNAF 1967 Canadian research report on)

Plaice (European) (*Pleuronectes platessa*)
J 26(12): 3237 (mathematical treatment of growth & feeding)

Plankton (*see also* Algae; Feed; Phytoplankton; Zooplankton)
J 26(2): 199 (estimating zooplankton production from phytoplankton production)
(7): 1948 (2 useful devices for vertical sampling)
(8): 2135 (composition & horizontal distribution of L. Ontario crustacean)

Plasma (*see* Blood; Serum)

Plates, bony (of Agonidae)
J 26(6): 1467 (standardization of terminology for)

Platichthys stellatus (*see* Flounder, starry)

Platt, Trevor Charles
J 26(6): 1625 (extraction of chlorophylls; correction on J 26(8): 2264)
(9): 2345 (zooplankton biomass equivalents)

Platygobio gracilis (*see* Chub, flathead)

Plecoptera (*see also* Insects, aquatic)
J 26(5): 1157 (feed, habits, ecology, in small Que. stream)
T 130 : 223 (of Nfld. streams)
S 1268 (distribution of Que. stoneflies)

Plerocercoids (*see* names of helminth parasites)

Pleuronectes platessa (*see* Plaice (European))

Poacher, Atlantic sea (*Agonus decagonus*)
J 26(3): 597(F) (retinal structure re activity, etc.)

Poacher, blacktip (*Xeneretmus latifrons*)
J 26(9): 2319 (parasites, B.C.)

Poacher, sturgeon (*Agonus acipenserinus*)
J 26(9): 2319 (parasites, B.C.)

Poacher, warty (*Occa verrucosa*)
J 26(6): 1467 (new Canadian records & plate terminology standardization)

Podonominae
B 170 (descriptions, morphology, taxonomy, distribution, etc. of 4 species)
T 124 (classification of Nearctic)

Poison (*see* Paralytic shellfish poisoning; Pollution; Toxicants)

Polinices heros (*see* Oyster drill, Atlantic)
lewisi (*see* Clam drill; Snail, moon)

Polistotrema stouti (*see* Hagfish, black)

Pollachius virens (*see* Pollock (Atlantic))

Pollack (*see* Pollock)

Pollock (Atlantic) (*Pollachius virens*)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)
A 119 (ICNAF 1967 Canadian research report on)

Pollock, walleye (*Theragra chalcogrammus*)
J 26(8): 1985 (stock & yield forecast, NE Pac. Ocean)
(9): 2319 (parasites, B.C.)
CNS 28 (B.C. commercial landings for animal feed)

Pollution (*see also* Eutrophication; Herbicides; Insecticides; Pesticides)
J 26(3): 695 (pesticides effect on brook trout & Atl. salmon)
(5): 1378 (spinner culture of mouse fibroblast cells to detect chemical water pollutants)
(7): 1931 (lobster larvae resistance to bleached kraft mill effluent)
(11): 2785 (copper sulphate effects on winter flounder tissues)
(11): 3055 (tetrachloro-*o*-benzoquinone in kraft mill effluent toxic to young Atl. salmon)
B 168 : 3 (re toxicity of shellfish)
169 : 140 (re Pac. oyster culture, B.C.)
T 130 (dissolved oxygen availability in Nfld. streams re industrial)
S 1276–1278 (kraft mill effluent toxicity to lobster & Atl. salmon)
1291 (antipollutant agent for protecting fish from zinc & copper)
1304 (biological effects of freshwater & marine)
1341 (eutrophication of inlet extension of Victoria harbour, B.C.)
A 132 (FRB research on)

Polychaeta
J 26(1): 55 (in Wash. coast benthic infauna standing crop)
(9): 2403 (as blackbelly eelpout feed)
(10): 2595 (new family: Acrocirridae)
(11): 3088 (range extension of *Manayunkya aestuarina* to B.C.)
T 116 (*Clymenella torquata* egg production)

Polydora ciliata (*see* Worm, boring sea)

Polymixia lowei (*see* Beardfish)

Polymorphism (*see* Phenotypes)

Polyteny
J 26(3): 543 (re *Pseudocalanus* size, cell & chromosome size differences in Ogac L., Baffin Is.)

Pomphorhynchus laevis (acanthocephalan)
J 26(4): 909 (in Atl. salmon, & use as indicator species)

Pope, M. A.
J 26(9): 2527 (line fishing off B.C.)

Populations (*see also* Stocks)
J 26(1): 15 (blood serum isoenzymes variants in different sockeye salmon)
(1): 123 (allometric weight–length regression model for fish)
(1): 179 (computer programming for estimation of exploited)
(2): 339 (DeLury estimator robustness)
(6): 1485 (zooplankton, Ogac L., Baffin Is.)
(6): 1585 (differences between Nfld. landlocked Atl. salmon)
(9): 2523 (polymorphic serum esterases of white bream & ruff)
(9): 2535 (bacterial kidney disease re possible distinction of E & W Atl. Ocean Atl. salmon)
(9): 2537 (meristic analysis of N American Atl. mackerel coastal)
(10): 2581 (bottom corer for estimating sedimentary benthic)
(10): 2633 (parameters of sablefish)
(11): 2843 (interpopulation dynamics model in marine ecology)
T 108 (studies of B.C. rock sole)
118 (razor clam, Masset, B.C.)
S 1271 (biology factors of Skeena R. system sockeye salmon)
1296 (aluminum staple tag for salmon smolt studies)
1334 (stream production limitations on salmonid)
1335 (production & genetic factors in managed salmonid)

Porichthys notatus (*see* Midshipman, northern)

Poromya (*Dermatomya*) *canadensis* (septibranchid bivalve)
J 26(8): 2230 (new NE Pac. species)

Porpoise, dall (*Phocoenoides dalli*)
B 171 : 27 (description, records, etc., of B.C.)

Porpoise, Pacific harbour (*Phocaena phocaena*)
B 171 : 26 (description, records, etc., of B.C.)

Porrocaecum (nematodes)
J 26(9): 2319 (in B.C. marine fishes)

Portage Inlet, Victoria harbour, B.C.)
S 1341 (eutrophication)

Post, George
J 26(8): 2247 (virus in trout pancreatic tissue)

Potassium compounds
J 26(2): 413 (cation concentration in Atl. salmon semen)
T 114 (potassium content of Atl. & Pac. herring meals)
S 1273 (partial molal volume of chloride, sulphate, bicarbonate, & nitrate in sea water)

Power, Geoffrey
J 26(6): 1585 (Nfld. landlocked Atl. salmon)

Power, Henry Edwin
T 114 (Atl. coast herring meals)
S 1339 (fluoride in biological samples)
A 125 (Halifax process products production costs)

Powles, Percival Mount
J 26(5): 1205 (equilibrium yields of American plaice)

Praecidochondria galatheae (copepod)
S 1301 (new genus & species parasite of a Malayan fish)

Prakash, Anand
S 1320 (growth of marine phytoplankton)
1321 (foraminiferal tests, planktonic organisms, & lithogenic particles in Bedford Basin, N.S.)

Prawn (*Pandalus platyceros*)
CNG 87 (experimental trap fishing of B.C.)
A 128 (condensed version of CNG 87 above)

Predation (*see also* Feed)
J 26(2): 361 (birds on sand-burrowing amphipods)
(5): 1273 (Atl. cod & haddock on other fishes)
(6): 1605 (of zooplankton standing stocks by *Cyclops*)
(6): 1672 (in & on aggregations of spottail shiners + yellow perch)
(12): 3183 (differential, of western mudminnow on red vs. black threespine sticklebacks)
B 169 : 154 (types of, and control, re Pac. oyster culture in B.C.)
T 121 (computer analysis program for feeding heterogeneities re predator body size)

Preservatives and preservative treatments (*see also* Antibiotics; Energy, radiant; Freezing; Refrigeration; etc.)
J 26(5): 1400 (cryo-refrigeration of steelhead trout semen)
(10): 2651 (EDTA effect on fillet spoilage characteristics)
A 130 (general, re fish muscle & products)

Pressure, osmotic
J 26(2): 413 (Atl. salmon seminal components)

Prest, Janice Elaine
T 117 (B.C. trawl fishery 1968)

Prickleback, black (*Xiphister atropurpureus*)
J 26(9): 2319 (parasites, B.C.)

Primary productivity (*see* Productivity, primary)

Prince Edward Island (*see also* Bideford River; Malpeque Bay)
J 26(3): 709 (first northern redbelly dace record)
A 138 (queen crab)

Prionace glauca (*see* Shark, blue)

Pristane
S 1286 (content of eulachon oil)

Pristanic acid (*see* Acids, fatty)

Production (*see also* Catches; Fisheries; *also* names of commercial organisms)
J 26(3): 479 (size-selective mortality & sampling bias effects on estimates of)
(6): (1485 ecology, of zooplankton in Ogac L., Baffin Is.)
B 169 : 112 (Pac. oyster, B.C.)

Productivity (*see also* Benthos; Epibenthos)
T 130 (factors affecting, for many Nfld. streams)

Productivity, primary
J 26(2): 199 (estimating zooplankton production from phytoplankton production in NE Pac. Ocean; corrections on J 26(8): 2264)
(5): 1363 (Owikeno L., re sockeye salmon)
(6): 1561 (Ogac L., Baffin Is.)
(8): 2003 (epibenthic, in Marion L. sediments, B.C.)
(9): 2345 (caloric & carbon equivalent of zooplankton biomass)
(12): 3165 (winter, Strait of Georgia, B.C.)
T 110 (Strait of Georgia, 1965–68)
S 1295 (& secondary: critical indices in large-scale ocean surveys)
1303 (bacterial decomposition of marine sedimentary organic debris)
1326 (re organic particulate matter as substrate for heterotrophic bacteria)

Prolactin
J 26(7): 1837 (immunohistochemical localization in sockeye salmon pituitary)

Prosopium cylindraceum (*see* Whitefish, round)
williamsoni (*see*, Whitefish, mountain)

Protein (*see also* Acids, amino; Composition, chemical; Fish protein concentrate; Proteolysis)
J 26(5): 1397 (polymorphism in harp seal blood)
(7): 1813 (maintenance level for bluegill)
(8): 2030 (content of beach-spawning Nfld. capelin)
(8): 2101 (serum: changes in, during lobster moult & reproduction)
(9): 2363 (content of young sockeye salmon re feed conversion efficiency)
(10): 2727 (fatty acids reaction with Atl. cod muscle protein iced then frozen)
(11): 2843 (content of steelhead trout during parr-to-smolt transformation)
T 114 (total, water soluble & amino acids, of Canadian Atl. herring meals)
S 1347 (amino acid composition re secondary structure of)

Protein concentrate (*see* Fish protein concentrate)

Proteolysis (*see also* Protein)
J 26(5): 1392 (of foreign protein in lobster)

Protohaustorius deichmannae (sand-burrowing amphipod)
J 26(5): 1321 (ecology & life cycle)
(9): 2283 (tolerances & behaviour)

Protothaca staminea (*see* Clam, native littleneck)

Protozoa (*see also* Zooplankton)
J 26(2): 299 (bacteriovorous, in Puget Sound plankton & benthos)
(4): 725 (taxonomy, re fish parasitization)
(4): 1075 (haematozoan (1 new species) from N.B. & New England marine fishes)
(6): 1485 (*Ptychocylis obtusa* ecology, Ogac L., Baffin Is.)
(8): 2016 (partitioning community respiration in lake sediments)
(9): 2459 (seasonal abundance, distribution, & composition, L. Erie)
(9): 2535 (re salmon kidney disease)
B 169 : 20 (*Cristispira* spirochaete associated with Pac. oyster crystalline style)
169 : 154 (parasites of Pac. oyster, B.C.)
S 1285 (axenic culture of flagellate *Hexamita inflata* from Atl. oyster)

Psenes maculatus (*see* Driftfish, silver)

Pseudocalanus
J 26(3): 543 (polyteny & size variation in 2 semi-landlocked fiords, Baffin Is., N.W.T.)
(6): 1485 (*P. minutus* population & production ecology, Ogac L., Baffin Is.)
(6): 1631 (young chum salmon growth on *P. minutus*)

Pseudomonas (*see also* Bacteria)
J 26(10): 2651 (population on vaccuum- vs. air-packaged EDTA-treated fish fillets)
(10): 2659 (*P. fluorescens* & other species ingested by oligochaetes in Toronto harbour sediments)
(10): 2760 (in culturing algal feed for rearing bivalve larvae)
S 1303 (re utilization of marine sedimentary organic debris)

Pseudopleuronectes americanus (*see* Flounder, winter)

Pseudorca crassidens (*see* Whale, false killer)

Pseudostylochus ostreophagus (flatworm)
B 169 : 87 (introduced to B.C. & Wash. with oyster seed from Japan)

Psychrolutes paradoxus (*see* Sculpin, tadpole)

Pteridines
J 26(5): 1185 (in coho salmon belly skin)

Ptilota serrata (seaweed)
J 26(10): 2703 (photo)

Ptychocylis obtusa (a tintinnid)
J 26(6): 1534 (Ogac L., Baffin Is.)

Publications and Reports, Fisheries Research Board of Canada
J 26(1): 197; (2): 477; (3): 711; (5): 1405; (6): 1697; (7): 1967; (8): 2265; (9): 2541; (10): 2773; (11): 3099 (lists of FRB investigations published in other periodicals. *See* list of Studies No. 1263–1355 following index in J 26(12))
(12): (list of 1969 & some late 1968)
AR 1968 (Annual Report, 1968)
R 1967/1968: 104 (list of 1967 & 1968)

Puget Sound, Washington
J 26(1): 55 (benthic infauna standing crop)
(2): 299 (planktonic & benthic bacteriovorous Protozoa)

Pugh, John Richard
J 26(7): 1956 (tank to simulate reservoir conditions)

Pugheadedness
J 26(11): 3091 (in landlocked Atl. salmon does not affect its life)

Pulp mill effluents (*see* Pollution)

Pungitius pungitius (*see* Stickleback, ninespine)

Punjamapirom, Somsee
J 26(8): 2027 (Nfld. capelin composition)

Purification (*see also* Pollution)
B 169: 147 (Pac. oyster, B.C.)

Purines (*see also* Acids, nucleic; Nucleotides)
J 26(3): 704 (inosine & hypoxanthine in canned Arabian Sea shrimp)
(5): 1185 (in coho salmon belly skin)
(6): 1597 (hypoxanthine as quality index of frozen sword fish)
(7): 1927 (quanine, hypoxanthine, etc. source of silvering of freshwater fishes skin, swim bladder, and eye)
(10): 2621 (re critical freezing zone of Atl. cod muscle)

Pycnopodia helianthoides (*see* Starfish, sun)

Pyruvate
S 1322 (metabolism by Atl. salmon eggs)

Q

Quahaug (*Mercenaria mercenaria*) (hard clam)
J 26(10): 2760 (bacterial flora of some algal feeds for rearing larvae)

Quahaug, ocean (*Arctica islandica*)
T 101 (obstacles & opportunities re utilizations)

Quality of fishery products
J 26(2): 357 (indirect colour enhancement of trouts & pink salmon flesh)
(3): 704 (canned shrimp re nucleotides)
(5): 1368 (muscle fluorescence re fish freshness)
(6): 1597 (re frozen swordfish muscle nucleotides)
(8): 2234 (colour of raw & cooked Atl. salmon flesh vs. canned Pac. salmons flesh)
(9): 2299 (re oxidative rancidity)
(9): 2523 (effect of seawater chilling on improving scallop meats keepability)
(10): 2651 (EDTA effect on petrale sole & Pac. ocean perch spoilage characteristics)
(12): 3175 (new enzymic activity test for ice-storage age of fresh gutted haddock)

(12): 3217 (bacteriology of Nfld. commercial fillets from cod & flounder variously handled at sea)
(12): 3271 (evaluations of freeze-dried vs. frozen Atl. cod steaks)
B 151 (F) (storage & keeping qualities of freshwater fishes products)
168 (re paralytic shellfish poisoning from B.C. shellfishes)
169 : 104, 109, 138, 140, 151 (Pac. oyster, B.C.)
CVG 41, 43, 44 (re chilling salmon, etc., on vessel before shore canning)
T 101 (experimentally canned & frozen ocean quahaug)
S 1290 (deterioration & storage life of frozen Atl. cod fish & fillets)
1309 (colour sorting of raw coho & sockeye salmon flesh re subsequent colour of canned)
A 130 (fish muscle, & its preservation)
138 (queen crab products)

Quayle, Daniel Branch
B 168 (paralytic shellfish poisoning)
169 (oyster culture in B.C.)
A 117 (B.C. marine borers)

Quebec Province (*see also* names of specific localities)
S 1268 (stoneflies distribution)
A 138 (queen crab)

Queen Charlotte Islands region, B.C. (*see also* Hecate Strait)
T 118 (razor clam populations study, Masset)

Quillback (*see* Sucker, quillback)

Quimby, Millicent Childs
J 26(9): 2511 (trout re infectious pancreatic necrosis virus)

Quinte, Bay of (Lake Ontario)
J 26(4): 833 (yellow perch parasites)

R

Rabbit
J 26(9): 2517 (vs. Pac. halibut dehydrogenase enzyme activity alteration by temperature, re animals' activity)

Radiation (*see* Energy, radiant; Light, reactions to; Radioactivity)

Radioactivity
S 1304 (uptake of radionuclides pollution by marine organisms)

Rafail, Samir Zaky
J 26(12): 3237 (plaice ration & growth relationship)

Raja erinacea (*see* Skate, little)
laevis (*see* Skate, barndoor)
ocellata (*see* Skate, winter)
radiata (*see* Skate, thorny)

Ramnarine, Arjoon
J 26(5): 1347 (*Euchaeta japonica* development)

Rancidity (*see also* Lipids)
J 26(9): 2299 (promoters & inhibitors of marine muscle lipids oxidation)
A 130 (general, of fish muscle & products)

Rangaswamy, J. R.
J 26(3): 704 (canned shrimp compounds)

Range extensions (*see* Species, new records)

Rashid, Mohammad Abdul
S 1320 (growth of marine phytoplankton)

Rations (*see also* Feed; Feedstuff; Hatchery)
J 26(9): 2363 (re growth rate & body composition of young sockeye salmon)

Rattail, pointed (*Coryphaenoides pectoralis*)
J 26(9): 2527 (in deepsea line fishing off B.C.)

Rattail, roughscale (*Coryphaenoides acrolepis*)
J 26(9): 2527 (in deepsea line fishing off B.C.)

Rausch, Robert Lloyd
J 26(4): 947 (cestodes from Hawaiian monk seal)

Ravesi, Elinor Mae
J 26(10): 2727 (protein in frozen cod muscle re free fatty acids)

Rayner, Martin Drake
J 26(8): 2208 (Pac. marine toxins: ciguatoxin not in vivo anticholinesterase)

Recipes
B 151(F) (for various products from freshwater fishes)

Records, new (*see* Species, new; Species, new records)

Recruitment (*see also* Mortality; Population; Stocks)
T 92 (computer program for equilibrium yield per recruitment for a fish stock)
108 (rock sole populations, N Hecate Strait, B.C.)
S 1316 (& size & age comparisons for Scotian Shelf haddock)

Redfish (*Sebastes marinus* (*mentella*))
CJG 16 (Nfld. landings, 1953–68 & 1968 details)
T 103 (in experimental otter-trawling, 1967)
A 119 (ICNAF 1967 Canadian research report on)

Redhorse, northern (*Moxostoma macrolepidotum*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Redhorse, silver (*Moxostoma anisurum*)
J 26(2): 325 (first Alta. record)

Reed, Paul Houston
J 26(2): 389 (Dungeness crab larvae survival)

Refrigeration (*see also* Freezing; Sea water, refrigerated; Thawing)
J 26(1): 154 (precise temperature controlled, for low-temperature fish)
(5): 1400 (cryo, of steelhead trout semen)
(8): 2037 (alterations in capelin lipids & fatty acids)
(8): 2237 (cryoprotective agents re rainbow trout muscle lipid hydrolysis during cold storage)
(9): 2523 (chilled seawater for improving keepability of scallop meats)
(10): 2727 (fatty acids reaction with Atl. cod muscle protein aged in ice then cold stored)
(12): 3217 (bacteriology of commercial Nfld. cod & flounder fillets from fish frozen whole or gutted at sea)
T 101 (experimentally frozen ocean quahaug quality)
S 1290 (deterioration & storage life of frozen Atl. cod fish & fillets)
A 130 (general, re fish muscle preservation)
138 (queen crab)

Refrigerated sea water (*see* Sea water, refrigerated)
Refsum's disease
S 1266 (phytanic acid re)

Regeneration
J 26(3): 671 (chum salmon scales, re aging)
(5): 1263; (6): 1619 (of marked sockeye & chum salmon fins)

Regier, Lloyd Wesley
CHN 35 (fillet freezing time & weight loss at −17 F)
S 1339 (fluoride in biological samples)

Reid, Sidney George
J 26(11): 3055 (tetrachloro-*o*-benzoquinone toxic to young salmon)

Reinhardtius hippoglossoides (*see* Halibut, Greenland)

Reproduction (*see also* Eggs; Fecundity; Spawning; Sperm; *also* names of organisms)
J 26(2): 361 (3 Haustoriidae amphipod species)
(2): 449 (regional pupping season differences in harbour seals)
(6): 1429 (re stream fishes ecology)
(8): 1969 (& fecundity of glass shrimp, Gulf of Maine)
(8): 2061 (behaviour of blackspotted stickleback)
(8): 2101 (changes in lobster protein serum during)
(9): 2403 (blackbelly eelpout, Burrard Inlet, B.C.)
(10): 2737 (delayed mating effects on king crab)
B 168 : 23 (Pac. oyster, B.C.)
A 117 (gribble)
138 (queen crab)

Reservoir
J 26(7): 1965 (experimental tank to simulate conditions in a)

Respiration (*see also* Activity; Blood; Gills; Lungs; Oxygen, dissolved; Respirometer)
J 26(1): 93 (temperature changes effects on acclimated Atl. salmon; respirometer apparatus)
(8): 2003 (benthic community, in sediments of Marion L., B.C.)
(10): 2643 (oxygen consumption metabolism re body weight: mathematical relations for several fishes)

Respirometer (*see also* Respiration)
J 26(1): 63, 93; (11): 2807 (for fish metabolism experiments)

Retina (*see* Eye)

Reviews
J 26(6): 1429 (distinctive aspects of stream fishes ecology)
(9): 2267 (Bertalanffy growth equation application to fishery management problems)
R 1967/1968 (Fisheries Research Board of Canada (biennial) Review)
S 1352 (Atl. cod biology, fishery, products, etc.)
A 122 (B.C. whaling)
123 (Nfld. salmon research, biology, fishery, etc.)
124–127 (Halifax Station development of fish protein concentrate)
130 (fishes muscle nutritional value re its preservation)

Rhabdochona (nematodes)
S 1267 (taxonomy re *Oncorhynchus* parasitism)

Rhacochilus vacca (*see* Perch, pile)

Rhamphocottus richardsoni (*see* Sculpin, grunt)

Rheotaxis (*see* Currents, reaction to)

Rhinichthys atratulus (*see* Dace, blacknose)
cataractae (*see* Dace, longnose)

Rhodophyceae (*see also* Seaweeds)
J 26(10): 2703 (of Halifax Co., N.S.)

Riboflavin (*see* Vitamin B group)

Ricker, William Edwin
J 26(3): 479 (effects of size-selective mortality)
(10): 2715 (simulated long-term environmental fluctuations on maximum sustained yield)
S 1268 (Que. stoneflies distribution)

Ridgeway, George J.
J 26(8): 2101 (lobster molt serum protein)

Riffenburgh, Robert Harry
J 26(11): 2843 (stochastic model of interpopulation dynamics in marine ecology)

Rigor
J 26(12): 3271 (effect on quality of freeze-dried Atl. cod steaks)

Roach (*Rutilus rutilus*)
J 26(11): 2795 (fecundity in R. Thames England)

Roach, Stewart Williard
CVG 41 (weight changes in Pac. coast fish stored at sea)
43, 44 (storage of Pac. salmon at sea)

Roberts, Eve
J 26(9): 2351 (halibut transferrin systems)
(10): 2633 (sablefish muscle protein polymorphism)

Roberts, Larry Spurgeon
J 26(4): 997 (*Ergasilus arthrosis* n.sp., & taxonomic status of *E. versicolor*, *E. elegans*, & *E. celestis*)

Roccus chrysops (*see* Bass, white)

Rockfish, flag (*Sebastodes rubrivinctus*)
J 26(7): 1955 (range extension westward to Aleutian Is.)

Rockfish, black (*Sebastodes melanops*)
J 26(9): 2319 (parasites, B.C.)
(11): 3094 (occurrence in open N Pac. Ocean, vs. usual demersal habitat)

Rockfish, blackgill (*Sebastodes melanostomus*)
T 132 : 7 (size composition)

Rockfish, blackthroat (*Sebastodes aleutianus*) (rougheye rockfish)
J 26(9): 2527 (in deepsea line fishing off B.C.)

Rockfish, copper (*Sebastodes caurinus*)
J 26(9): 2319 (parasites, B.C.)

Rockfish, greenstripe (*Sebastodes elongatus*)
J 26(9): 2319 (parasites, B.C.)

Rockfish, quillback (*Sebastodes malinger*)
J 26(9): 2319 (parasites, B.C.)

Rockfish, rougheye (*see* Rockfish, blackthroat)

Rockfish, splitnose (*Sebastodes diploproa*)
J 26(9): 2319 (parasites, B.C.)

Rockfish, yellowtail (*Sebastodes flavidus*)
J 26(8): 2211 (feed ecology in Astoria Canyon off mouth of Columbia R.)

Rockfishes (Pacific)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 113 (catches of 14 *Sebastodes* species in research trawling off W coast Vancouver Is., 1969)
117, 131 (B.C. commercial trawl landings, 1968)

Roktee cotio (an India freshwater fish)
J 26(4): 965 (host of new acanthocephalan species, *Acanthosentis cameroni*)

Ronquil, northern (*Ronquilus jordani*)
J 26(9): 2319 (parasites, B.C.)

Rosefish, blackbelly (*Helicolenus dactylopterus*)
J 26(10): 2698 (two new Canadian Atl. specimens)

Ross, Avron John
J 26(1): 115 (endotoxins in salmonids)

Ross, Herbert Holdsworth
S 1268 (Que. stoneflies distribution)

Rotifera
J 26(6): 1536 (*Synchaeta tamara*, Ogac L., Baffin Is.)
(9): 2459 (seasonal abundance, distribution, & composition, L. Erie)
(12): 3101 (of Crecy L., N.B.)

Roundworms (*see* Nematoda)

Rowe, Virginia Leslie
T 116 (observations on *Clymenella torquata*)

Ruff (*Acerina cernua*)
J 26(9): 2532 (polymorphic serum esterases suited for population analysis)

Ruff, black (*Centrolophus niger*)
J 26(10): 2698 (another Canadian Atl. specimen)

Runner, blue (*Caranx crysos*)
J 26(10): 2769 (first Gulf of St. Lawrence record)

Rutilus rutilis (*see* Roach)

S

Saanich Inlet, B.C.
T 99 (water movement features over sill)
110 (biological oceanography observations summary, 1965–68)

Sabah (formerly North Borneo)
J 26(4): 793 (checklist of nematodes from fishes, amphibians, and reptiles)

Sabinea septemcarinata (a crangonid shrimp)
J 26(7): 1899 (W Canadian Arctic)

Sable Island, N.S.
J 26(5): 1390 (distribution of 4 insular fishes)

Sablefish (*Anoplopoma fimbria*) (blackcod)
J 26(9): 2319 (parasites, B.C.)
(9): 2529 (in deepsea line fishing off B.C.)
(10): 2633 (muscle protein polymorphism re population parameters)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
CVG 41 (weight changes during holding in refrigerated sea water vs. ice)
T 107 (tank culture)
117, 131 (B.C. commercial trawl landings, 1968)
132 (catches in experimental B.C. trawling)

Sæther, Ole Anton
B 170 (Nearctic Podonominae, Diamesinae, and Orthocladiinae)
T 124 (Nearctic Chironomidae classification)

Safsten, Gunnar Carl
J 26(3): 671 (chum scales re age)

Sagitta elegans (a chaetognath)
J 26(6): 1485 (ecology, etc., Ogac L., Baffin Is.)
(7): 1743 (experiments re feeding habits)

Saito, Akira
J 26(8): 2234 (Atl. salmon color)

Salinity (*see also* Oceanography)
J 26(10): 2746 (1968, in & off Gulf of Maine)
T 120 (Bedford Basin, N.S.)
S 1280 (St. John's–Flemish Cap section, Nfld.)

Salinity, reactions to
J 26(2): 389 (Dungeness crab larvae growth & survival)
(3): 639 (American eel renal physiology)
(3): 701 (estuarine fauna mass mortality due to low salinity)
(9): 2283 (5 haustoriid amphipod species)
(11): 2807 (re oxygen consumption & swimming speed of *Tilapia nilotica*)
(12): 3183 (of eggs of red vs. black threespine sticklebacks)
(12): 3248 (re swordfish spawning in W Atl.)
T 136 (re swordfish spawning in W Atl.)

Salmincola (parasitic copepods)
J 26(9): 2319 (*S. californiensis* on coho salmon)
(11): 2987 (revision of the genus, re *Achtheres* genus)
(11): 3017 (key to)
T 134 (*S. salmoneus* as indicator for distinguishing Atl. salmon stocks)

Salmo aquabonita (*see* Trout, golden)
clarki (*see* Trout, cutthroat)
gairdneri (*see* Trout, rainbow; Trout, steelhead)
salar (*see* Salmon, Atlantic; Salmon, Atlantic landlocked)
trutta (*see* Trout, brown)

Salmon (Pacific, in general) (*see also* names of individual species)
J 26(11): 2987 (parasitization by *Salmincola* copepods)
CVG 42 (canning waste water clarification & solids recovery)
T 123 (clearing & staining young, for skeletal studies)
S 1267 (3 Japanese nematode genera taxonomy, re parasitism of)
1298–1300 (parasitic nematodes of swim bladder)
1334 (limitations re stream populations production)
1335 (production & genetic factors in managed populations)
A 118 (swimming speed performance levels)

Salmon, Atlantic (*Salmo salar*) (*see also* Salmon, Atlantic landlocked)
J 26(1): 47 (DDT in vitro degradation by intestinal bacteria)
(1): 93 (temperature changes effects on activity & respiration)
(2): 269 (migration of NW Margaree R., N.B., to various commercial & sport fishery areas)
(2): 413 (cations, osmotic pressure, & *p*H of seminal constituents)
(3): 695 (mass mortalities & behaviour in pesticide-polluted stream)
(4): 909 (*Pomphorhynchus laevis* acanthocephalan parasite used as distribution indicator)
(4): 975 (*Bothrimonus* cestode parasite biology)

(6): 1661 (scale characteristics during fifth & sixth spawning trips)
(6): 1694 (muscle damage from nylon gillnetting)
(7): 1867 (stream dispersal of wild vs. hatchery-reared juveniles)
(8): 2093 (swim bladder, etc. re parr & smolt buoyancy)
(8): 2234 colour in raw & cooked flesh vs. canned Pac. salmons flesh)
(9): 2535 (bacterial kidney disease, re possible distinction between E & W Atl. Ocean populations)
(11): 2987 (parasitization by *Salmincola* copepods)
(11): 3055 (toxicity of a kraft mill effluent component to)
(12): 3254 (freezing spermatozoa with extender)
(12): 3259 (infectious pancreatic necrosis virus in hatchery-held young Atl.)
CJG 16 (W Greenland & high seas fishery)
T 91 (analysis of 1966 smolt run in NW Miramichi R., N.B.)
93 (freezing sperm with extenders & protective agents)
130 (catches & weights angled in Nfld. streams)
134 (parasites as biological indicators)
S 1276–1278 (toxicity of kraft mill effluent to young)
1317 (distribution & characteristics, banks & deeps off Nfld.)
1322 (pyruvate & glyoxylate metabolism by eggs)
1342 (aminotransferases in eggs & sperm)
A 119 (ICNAF 1967 Canadian research report on)
123 (review of Nfld. research, biology, fishery, etc.)

Salmon, Atlantic landlocked (*Salmo salar*) (ouananiche; sebago salmon)
J 26(6): 1585 (differences between 2 Nfld. populations)
(11): 3091 (pugheadedness does not affect life of)

Salmon, biwa (*Oncorhynchus rhodurus*)
S 1267 (nematode parasites)

Salmon, chinook (*Oncorhynchus tshawytscha*) (*see also* Salmon (Pacific, in general))
J 26(8): 2111, 2123 (olfactory discrimination of natural waters)
(9): 2319 (parasites, B.C.)
(10): 2765 (branding young with tool cooled by liquid nitrogen)
S 1292, 1336 (pituitary gonadotropin induction of spermatogenesis & ovulation in hypophysectomized goldfish)
1308 (blood plasma protein binding of steroids)

Salmon, chum (*Oncorhynchus keta*) (*see also* Salmon (Pacific, in general))
J 26(3): 671 (aging from scales)
(4): 893 (maturation of 2 hemiurid trematode species in)
(5): 1199 (aging from pectoral fin rays)
(6): 1631 (growth of young on euphausid vs. copepod feed)
(8): 2219 (feed of juvenile in Chatham Sound area, B.C.)
(8): 2234 (colour of canned flesh vs. raw & cooked Atl. salmon flesh)
(9): 2319 (parasites, B.C.)
CNS 27 (age composition of 1967 B.C. commercial catches)
S 1297 (enzymic degradation of egg capsule during hatching)
1302 (in open N Pac. Ocean waters)
1305 (marine microorganisms associated with feed of young)
1308 (blood plasma protein binding of steroids)

Salmon, coho (*Oncorhynchus kisutch*) (*see also* Salmon (Pacific, in general))
J 26(1): 63 (fry competitiveness re hypoxial stress of egg & fry)
(1): 111 (anemia from folic acid deficiency in feed)
(1): 115 (metabolic effects of bacterial endotoxins)
(1): 133 (fry trap for estimating egg-to-fry-emergence survival)
(5): 1185 (ultraviolet-absorbing & -fluorescing substances in fry belly skin)
(6): 1619 (tests of fluorescent pigment marking vs. finclipping re fry survival)
(8): 2111, 2123 (olfactory discrimination of natural waters)
(8): 2219 (feed of juvenile in Chatham Sound area, B.C.)
(8): 2234 (colour of canned flesh vs. raw & cooked Atl. salmon flesh)
(9): 2319 (parasites, B.C.)
(10): 2765 (branding of young with tool cooled by liquid nitrogen)
(11): 3083 (detector for magnetized wire tags)
(12): 3209 (DDT lack of effect on hepatic dehydrogenase activity)
S 1298 (inosinic & uridylic acids de novo biosyntheses in testes & liver)
1297 (enzymic degradation of egg capsule during hatching)
1299, 1300 (*Salvelinema walkeri* nematode parasite in swim bladder)
1305 (marine microorganisms associated with feed of young)
1308 (blood plasma binding of steroids)
1309 (colour sorting of raw flesh re subsequent colour of canned)
1332 (ecological implications of diet of young in streams)

Salmon, kokanee (*see* Kokanee)

Salmon, masu (*Oncorhynchus masou*)
S 1267 (nematode parasites)

Salmon, pink (*Oncorhynchus gorbuscha*) (*see also* Salmon (Pacific, in general))
J 26(2): 357 (adding canthaxanthin to feed of young, to enhance flesh colour)
(4): 813 (early sea life parasites of Bella Coola, B.C.)
(4): 893 (maturation of 2 hemiurid trematode species in)
(4): 975 (*Bothrimonas* cestode biology in)
(8): 2219 (feed of juveniles in Chatham Sound area, B.C.)
(8): 2234 (colour of canned flesh vs. raw & cooked Atl. salmon flesh)
(9): 2319 (parasites, B.C.)
CJG 16 22 (1968 returns from 1966 egg transplantation from B.C. to Nfld.)
CNS 27 (age composition of 1967 B.C. commercial catches)
CVG 41 (weight changes during holding in refrigerated sea water vs. ice)
43 (effect of delay in chilling in refrigerated sea water on vessel, re quality of canned)
T 111 (ova & milt re spawn collection)
A 119 (ICNAF 1967 Canadian research report on transplanted to Nfld.)
123 : 348 (results of transplanting to Nfld.

Salmon, sebago (*see* Salmon, Atl. landlocked)

Salmon, sockeye (*Oncorhynchus nerka*) (*see also* Kokanee; Salmon (Pacific, in general))
J 26(1): 15 (blood serum lactate dehydrogenase isoenzymes variants in different populations)
(2): 229 (fry distribution, growth, & survival, from natural vs. artificial stream rearing, Babine L., B.C.)
(3): 655 (variance components in estimating egg deposition potential, Bristol Bay)
(4): 849 (*Cystidicola* nematode in swim bladder)
(4): 941 (invasion route of dracunculoid nematode to swim bladder)
(5): 1147 (pituitary cytology after gonadectomy)
(5): 1199 (aging from pectoral fin rays)
(5): 1263 (finclipping effect on survival)
(5): 1363 (re primary productivity of Owikeno L., B.C.)
(5): 1383 (swimming thrust re gillnet mesh selectivity)
(7): 1789 (estrogens & cortisol injection effects on cortisol secretion of gonadectomized female)
(7): 1837 (immunohistochemical localization of ACTH & prolactin in pituitary)
(8): 2219 (feed of juvenile in Chatham Sound area, B.C.)
(8): 2234 (colour of canned flesh vs. raw & cooked Atl. salmon flesh)
(9): 2319 (parasites, B.C.)
(9): 2363 (fingerling growth rate & body composition re temperature & ration size)
(10): 2643 (oxygen metabolism re body weight)
(10): 2741 (weight on length regression re rapid average weight estimation of young)
(10): 2765 (branding young with tool cooled by liquid nitrogen)
(11): 2975 (gonadectomy re interrenal tissue hypertrophy in sexually maturing)
CNS 27 (age composition of 1967 B.C. commercial catches)
CVG 41, 44 (weight changes during holding in refrigerated sea water vs. ice)
43 (delay in chilling in refrigerated sea water on vessel, re effect on quality of canned product)
44 (delay in chilling in ice vs. refrigerated sea water re effect on handling, storage, & canning)
T 111 (ova & milt re spawn collection)
133 (scale characteristics, from Skeena R. system nurseries)
S 1271 (factors in population biology of Skeena R. system)
1296 (aluminum staple tag for smolt population estimates)
1308 (blood plasma binding of steroids)
1309 (colour sorting of raw flesh re subsequent colour of canned)
1310, 1338 (changes in cortisol dynamics re sexual maturation)
1333 (adaptations associated with incubation in gravel streams)
1340 (interrenal activity suppression by dexamethasone corticosteroid injection)
A 118 (swimming speed performance & metabolism)

Salmon, steelhead (*see* Trout, rainbow; Trout, steelhead)

Salt (sodium chloride)
J 26(8): 2030 (content of fresh beach-spawning Nfld. capelin)
T 114 (content of Atl. & Pac. herring meals)

Salvelinema (nematodes)
S 1298 (*S. salmonicola* & *S. walkeri* buccal structure)
1299, 1300 (parasites of Pac. salmons swim bladder)

Salvelinus alpinus (*see* Char, arctic)
fontinalis (*see* Trout, brook)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Salvelinus malma (*see* Dolly Varden)
namaycush (*see* Trout, lake)

Sameoto, Douglas Daniel
J 26(2): 361 (intertidal amphipods)
(5): 1321 (sand-burrowing amphipods)
(8): 2240 (otter surface sampler)
(9): 2283 (physiology of Haustoriidae)

Sampling; Sampling devices (*see also* Apparatus)
J 26(3): 479 (sampling bias effects on growth mortality, production, & yield estimates)
(7): 1948 (2 useful devices for vertical, of water & plankton)
(8): 1985 (re exploratory demersal fishing methods, NE Pac. Ocean)
(8): 2005 (lake sediment sampler)
(8): 2240 (net for zooplankton & ichthyoplankton)
(10): 2581 (corer for bottom-sampling benthos & sediments; efficiency comparison with Ekman grab)
(10): 2751 (sediment sampler attached to trawl board)
T 94–97 (Nfld. herring data & summary tabulations, 1964–65 to 1967–68)

Sand dollar (*Echinarachnius parma*)
J 26(7): 1965 (a hermaphrodite specimen of)

Sand lance (*Ammodytes* spp.)
J 26(8): 2219 (as feed of juvenile Pac. salmons)
A 119 (ICNAF 1967 Canadian research report on probably *A. dubius*)

Sand lance, Pacific (*Ammodytes hexapterus*)
J 26(9): 2319 (parasites, B.C.)

Sanddab, speckled (*Citharichthys stigmaeus*)
J 26(9): 2319 (parasites, B.C.)

Sandeman, Ian Muir
J 26(4): 975 (biology of *Bothrimonus*)

Sangalang, Gloria Josefina (Balolong)
S 1329 (steroid desmolase in a marine invertebrate)

Sarda chiliensis (*see* Bonito, Pacific)

Sardine, California (*see* Sardine, Pacific)

Sardine, Pacific (*Sardinops sagax*) (California sardine; Pilchard)
J 26(11): 2843 (interpopulation dynamics model re predators & prey, & forecasting of resultant catches)

Sardinops sagax (*see* Sardine, Pacific)

Saskatchewan River
J 26(6): 1439 (fishes distribution re Missouri R. headwaters in Canada)

Sauger (*Stizostedion canadense*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(7): 1927 (purine sources of skin silvering)

Saunders, John Wilfred
J 26(3): 695 (stream pollution by pesticides)

Saunders, Richard Lee
J 26(2): 269 (NW Miramichi R. salmon catches)

Sausage; Wiener
B 151(F) (from freshwater fishes)

Saux Head Lake, Michigan
J 26(11): 3077 (sea lamprey larvicides tests)

Savagaon, Kadayya Annayya
T 114 (Atl. coast herring meals)

Savitz, Jan
J 26(7): 1813 (sunfish nitrogen excretion)

Saxidomus giganteus (*see* Clam, butter)

Scad, bigeye (*Selar crumenophthalmus*)
J 26(10): 2769 (first Gulf of St. Lawrence record)

Scad, mackerel (*Decapterus macarellus*)
J 26(10): 2698 (new Canadian specimen off N.S.)

Scales, fish
J 26(1): 175 (re distinguishing northern pike vs. maskinonge)
(3): 633 (white sucker scales vs. fin rays for aging)
(3): 671 (chum salmon aging from)
(5): 1285 (annulus formation re age, longnose sucker)
(6): 1585 (unreliability for aging landlocked Atl. salmon)
(6): 1661 (erosion of repeatedly spawned Atl. salmon)
(7): 1889 (vs. otoliths for Atl. herring aging)
(8): 2082 (density, of herring)
(10): 2754 (steelhead trout aging from, Babine R., B.C.)
T 133 (characteristics, of Skeena R. system nursery areas sockeye salmon)
S 1302 (studies re origin of open N Pac. chum salmon)
A 123 : 351 (Nfld. salmon)

Scallop, giant or sea (*Placoplecten magellanicus*) (*see also* Scallop, weatherwane)
J 26(9): 2299 (promoters & inhibitors of muscle lipids oxidation)
(9): 2523 (effect of seawater chilling on meats quality)
T 102 : 4 (underwater observations from cubmarine)

S 1272 (phospholipids; in vivo incorporation of radioactive bases into phospholipids)
1284 (recent developments in Georges Bank fishery)
1329 (gonadal tissue enzyme capable of converting a C-21 to a C-19 steroid in vitro)
A 119 (ICNAF 1967 Canadian research report on)

Scallop, pink (*Chlamys rubida*)
T 104 (B.C. resources)

Scallop, (purple-hinged) rock (*Hinnites multirugosis*)
B 168 : 31 (toxicity record, B.C.)
T 104 (B.C. resources)

Scallop, sea (*see* Scallop, giant)

Scallop, spiny or rough (*Chlamys hastata hericia*)
T 104 (B.C. resources)

Scallop, weathervane or giant (*Pecten* (*Patinopecten*) *caurinus*)
T 104 (B.C. resources)

Scarratt, David Johnson
J 26(7): 1931 (bleached kraft mill effluent re lobster larvae)

Schafer, Charles Thomas
S 1321 (foraminiferal tests, planktonic organisms, & lithogenic particles in Bedford Basin, N.S.)

Schindler, David William
J 26(7): 1948 (devices for vertical plankton & water sampling)

Schistobranchia ramosus (parasitic copepod)
J 26(4): 805 (from Nfld. thorny skate)

Schistocephalus solidus (cestode)
J 26(4): 741 (culture, hosts, growth rate, & proglottid formation in plerocercoid)

Schmidt, Peter Joseph
J 26(2): 357 (salmon & trout pigmentation)
S 1309 (raw salmon color sorting)

Schooling
J 26(2): 393 (effect of light on jack mackerel)
(4): 711 (seasonal effect on yellow perch)
(5): 1372 (theory of fish school size re migration navigation)
(6): 1672 (aggregations of spottail shiners + yellow perch)

Scleroncrangon (crangonid shrimps)
J 26(7): 1889 (*S. ferox* & *S. boreas* in W Canadian Arctic)

Scomber scombrus (*see* Mackerel, Atlantic)

Scomberomorus maculatus (*see* Mackerel, Spanish)

Scotian Shelf waters, off N.S.
T 86 (Canadian cod & haddock catches, 1965)
S 1316 (size, age, & recruitment comparisons for haddock)

Scotland
S 1348 (rare fishes from Clyde sea area)

Scott, James Stuart
J 26(4): 879 (trematodes as biological indicators)
S 1287 (*Lampritrema nipponicum* from W Atl. argentines)
1354 (rostellar hooks of *Paricterotaenia paradoxa*)

Scott, Kenneth Randall
J 26(1): 154 (fish storage facility)

Scott, William Beverly
J 26(10): 2691 (mesopelagic & other fishes from Canadian Atl.)

Screen
S 1345 (retention of marine particles by)

Sculpin, blackfin (*Malacottus kincaidi*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, great (*Myoxocephalus polyacanthocephalus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, grunt (*Rhamphocottus richardsoni*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, little (*see* Grubby)

Sculpin, longfin (*Jordania zonope*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, longhorn (*Myoxocephalus octodecemspinosus*)
J 26(3): 597(F) (retinal structure re activity, etc.)

Sculpin, mailed (*Triglops murrayi*)
J 26(2): 473 (Gulf of Maine occurrences & spawning)
(3): 597(F) (retinal structure re activity, etc.)

Sculpin, mottled (*Cottus bairdi*)
J 26(2): 325 (in S Alta.)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Sculpin, Pacific staghorn (*Leptocottus armatus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, padded (*Artedius fenestralis*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, ribbed (*Triglops beani*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, roughback (*Chitonotus pugetensis*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, sailfin (*Nautichthys oculofasciatus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, scalyhead (*Artedius harringtoni*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, shorthorn (*Myoxocephalus scorpius*)
J 26(3): 597(F) (retinal structure re activity, etc.)
(4): 805 (*Phyllobothrium parvum* in intestine)

Sculpin, silverspotted (*Blepsias cirrhosus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, soft (*Gilbertidia sigalutes*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, spinyhead (*Dasycottus setiger*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, spoonhead (*Cottus ricei*)
J 26(2): 325 (S Alta. distribution)

Sculpin, spotfin (*Icelinus tenuis*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, tadpole (*Psychrolutes paradoxus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, threadfin (*Icelinus filamentosus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, tidepool (*Oligocottus maculosus*)
J 26(9): 2319 (parasites, B.C.)

Sculpin, twohorn (*Icelus bicornis*)
J 26(10): 2699 (range extension S to off S N.S.)

Sculpin, woolly (*Clinocottus analis australis*)
J 26(4): 957(F) (*Opegaster cameroni* new trematode species from)

Scup (*Stenotomus chrysops*)
J 26(10): 2698 (off Grand Manan, N.B.)

Sea anemone
J 26(1): 145 (zinc content of a deep-sea)

Sea cucumber (*see also* Echinoderms)
A 133 (caloric content of 3 species)

Sea lion, California (*Zalophus californianus*)
B 171 : 42 (records, B.C.)

Sea lion (Peru) (*Otaria byronia*)
J 26(4): 713 (*Diphyllobothrium* & other parasites in)

Sea lion, Steller or northern (*Eumetopias jubatus*)
B 171 : 41 (description, records, etc. of B.C.)

Sea poacher, Atlantic (*see* Poacher, Atlantic sea)

Sea stars (*see* Starfish)

Sea urchins (*see also* Echinoderms)
J 26(10): 2669 (ciliate & turbellarian parasites of *Strongylocentrotus franciscanus*)
A 133 (caloric content of *Strongylocentrotus*)

Sea water (*see also* Oceanography; Salinity; etc.)
S 1273 (partial molal volumes of 16 salts in)

Sea water, refrigerated (for holding fishery products)
J 26(9): 2523 (for improving scallop meat quality)
CVG 41, 44 (weight changes of some B.C. fishes stored at sea in, vs. icing)
44 (effect on yield prior to, & during canning of sockeye salmon)
A 138 (queen crab)

Seal, harp (*Pagophilus groenlandicus*)
J 26(5): 1397 (blood protein polymorphism)
A 119 (ICNAF 1967 Canadian research report on)

Seal, hooded (*Cystophora cristata*)
A 119 (ICNAF 1967 Canadian research report on)

Seal, monk (Hawaiian) (*Monachus schauinslandi*)
J 26(4): 947 (3 *Diphyllobothrium* parasite species histology)

Seal, northern elephant (*Mirounga angustirostris*)
B 171 : 44 (occurrences & sightings in B.C. waters)

Seal, northern fur (*Callorhinus ursinus*)
B 171 : 39 (description, records, etc., of B.C.)

Seal, Pacific harbour (*Phoca vitulina richardi*)
J 26(2): 449 (regional differences in pupping season of 4 subspecies)
B 171 : 43 (description, records, etc., of B.C.)
172 : (life history of, in B.C.)

Seaweeds (*see also* Algae; *also* classifications & certain generic & popular names)
J 26(1): 145 (zinc content)
(10): 2703 (preliminary survey, Halifax Co., N.S.)

Sebastes marinus (*mentella*) (*see* Redfish)

Sebastodes aleutianus (*see* Rockfish, blackthroat)
alutus (*see* Perch, Pacific Ocean)
caurinus (*see* Rockfish, copper)
diploproa (*see* Rockfish, splitnose)
elongatus (*see* Rockfish, greenstriped)
flavidus (*see* Rockfish, yellowtail)
maliger (*see* Rockfish, quillback)
melanops (*see* Rockfish, black)
melanostomus (*see* Rockfish, blackgill)
rubrivinctus (*see* Rockfish, flag)

Sediments
J 26(1): 55 (particle size analysis, Wash. coast)
(6): 1667 (separation of invertebrates from, by fluorescent dyes)
(7): 1959 (chemical estimation of caloric content of marine)
(8): 2003 (epibenthic algae & community respiration in Marion L., B.C.)
(9): 2283 (size preferences of 5 haustoriid amphipod species)
(10): 2581 (bottom corer for sampling)
(10): 2659 (bacteria & amino acids in Toronto harbour, as nutritional resources)
(10): 2751 (bottom sampler attached to trawl board)
B 169 : 96 (re Pac. oyster culture)
CVG 42 (solids recovery from salmon-canning & herring-pumping waste waters)
S 1303 (bacteria role in primary production from organic debris in marine)
1321 (current transport of marine sediment-forming materials, Bedford Basin, N.S.)
1353 (Gulf of St. Lawrence: types, minerals, geomorphology; iron, aluminum, sodium/potassium ratio values)

Seki, Humitake
J 26(12): 3165 (zooplankton food in winter in Strait of Georgia, B.C.)
S 1303 (marine sediment decomposition)
1305 (food of young salmon)
1326 (allochthonous bacteria and organic materials)

Selar crumenophthalmus (*see* Scad, bigeye)

Selectivity of fishing gear (*see also* Nets)
J 26(5): 1205 (re American plaice fishery)
(5): 1383 (gillnets, re sockeye salmon swimming thrust)
(10): 2681 (gillnets, re fish shape & structure)
S 1317 (Atl. salmon in experimental drift net fishing)

Seman, John Peter, Jr.
J 26(10): 2651 (EDTA on spoilage of petrale sole & ocean perch fillets)

Semen; Sperm; Milt (*see also* Reproduction; Testes)
J 26(2): 413 (major cations, osmotic pressure, & *p*H of Atl. salmon)
(5): 1400 (steelhead trout fertilization results with cryo-preserved)
(12): 3254 (freezing Atl. salmon spermatozoa with extender)
T 93 (freezing Atl. salmon sperm with extenders & protective agents)
111 (& ova of sockeye & pink salmon re spawn collection)
S 1342 (aminotransferases in Atl. fishes)

Semontilus margarita nachtriebi (*see* Dace northern pearl)

Senecella calanoides
J 26(10): 2543 (life cycle & vertical distribution, Parry Sound, Ont.)

Sepic, Kresimir
J 26(8): 2257 (heading & gutting capelin)

Septibranchida (bivalves)
J 26(8): 2230 (description of 5 new NE Pac. species)

Sergeant, David Ernest
J 26(8): 2201 (tagging white whales)
(10): 2561 (body size in white whales)

Sergestes similis (*see* Shrimps (Pacific))

Serum; Serology (*see also* Blood)
J 26(1): 15 (lactate dehydrogenase isoenzymes variants in, of sockeye salmon populations)
(5): 1397 (polymorphism in harp seal blood protein)
(8): 2101 (protein: changes in, during lobster moult & reproduction)
(9): 2351 (Pac. halibut blood serum proteins)
(9): 2532 (white bream & ruff polymorphic esterases)
(12): 3268 (transferrin variants in Pac. hake)
S 1288 (serum protein concentration of hemolymph as index of lobster condition)

Sex
J 26(8): 2041 (of capelin re fat content & lipid hydrolysis)
(12): 3262 (dimorphism in Pac. spiny lumpsucker)

Sex ratio
J 26(2): 361; (5): 1321 (sand-burrowing amphipods)
(3): 655 (sockeye salmon escapement, Bristol Bay, Alaska)
(5): 1285 (W L. Superior longnose suckers)
(10): 2754 (in steelhead trout sport fishery, Babine R., B.C.)
(12): 3133 (cod in fishery off SW Nfld.)

Sexual maturity (*see* Maturation)

Shanny, arctic (*Stichaeus punctatus*)
J 26(5): 1375 (first Massachusetts Bay record; morphology, feed)

Shape, of fish (*see also* Morphology)
J 26(10): 2681 (selectivity of gillnets, re)
(11): 2823 (changes in steelhead trout during parr-to-smolt transformation)

Shark, blue (*Prionace glauca*)
J 26(4): 805 (4 cestode species in Nfld.)

Shark, Greenland (*Somniosus microcephalus*)
J 26(1): 143 (sex, lengths, feed, & parasite, N Baffin Is.)

Sheepshead (*Aplodinotus grunniens*)
J 26(6): 1439 (distribution in Canadian Missouri R. headwaters)
B 151(F) (sausage products; canned)

Shelbourn, John Edward
J 26(9): 2363 (sockeye growth and composition)

Sheldon, Raymond Wilfred
J 26(1): 171 (Malpeque Bay, P.E.I., physiographic changes 1845–1955 re oyster production)
(10): 2751 (trawl-board sediment sampler)
S 1345 (marine particles retention)

Shell
B 169 : 8, 40, 57, 106 (Pac. oyster morphology, growth, uses, B.C.)
S 1315 (weight to total weight ratio re sexual dimorphism of Naticidae)

Shellfish (*see also* classification & species)
B 168; 169: 151 (paralytic shellfish poisoning from certain B.C.)

Shephard, Michael Perry
S 1302 (N Pac. Ocean salmon)

Shieh, Hang-shan
S 1272 (scallop phospholipids radioactive bases)
1312 (marine microbe fatty acid synthesis)
1346 (phospholipids in lobster)

Shiner, emerald (*Notropis atherinoides*)
J 26(2): 325 (S Alta. distribution)

Shiner, spottail (*Notropis hudsonius*)
J 26(6): 1672 (aggregations with yellow perch; predators)

Shipworms
T 119 (combatting attack of *Teredo navalis* on hulls)
A 121 (treating lobster traps against)

Shoop, Clifford Thomas
J 26(9): 2363 (sockeye growth and composition)

Shrimp (an Arabian sea) (*Metapenaeus dobsoni*)
J 26(3): 704 (nucleotides & related compounds in canned)

Shrimp, brine (*Artemia salina*)
J 26(3): 557 (northern anchovy feeding habit on nauplii vs. adult)

Shrimp, ghost (*Callianassa californiensis*)
B 169 : 156 (pest re Pac. oyster culture, B.C.)

Shrimp, glass (*Pasiphaea multidentata*)
J 26(8): 1969 (breeding, fecundity, feed, growth)

Shrimp, mud (*Upogebia pugettensis*)
B 169 : 156 (pest re Pac. oyster culture in B.C.)

Shrimp, striped pink (*Pandalus montagui*)
T 121 (used as example in computer program for predation study)
A 123 (caloric content)

Shrimps (arctic)
J 26(7): 1899 (Beaufort Sea to Cambridge Bay)

Shrimps (Atlantic)
J 26(11): 2969 (chemical composition & nutritive value of *Parapenaeus* spp.)
A 133 (caloric content of *Argis dentata*)

Shrimps (Pacific)
J 26(8): 2211 (*Sergestes similis* & *Pasiphaea pacifica* as yellowtail rockfish feed)
S 1328 (B.C. industry)

Shucking
B 169 : 104 (Pac. oyster, B.C.)

Silicate
J 26(5): 1133 (re marine phytoplankton growth)
T 120 (in Bedford Basin waters, N.S.)

Silicone
S 1275 (an organic, to produce nonwetting glass surface)

Siliqua patula (*see* Clam, Razor)

Silliman, Ralph Parks
J 26(1): 161 (growth in weight of fishes)

Simpson, S. L.
A 138 (queen crab industry in Atl. Provinces)

Simuliidae (*see also* Insects, aquatic)
J 26(5): 1157 (feed, habits, ecology, in small Que. stream)

Sinistrality
J 26(1): 191 (S to N percentage increase in B.C. starry flounders)

Size (*see also* Age; Growth; Length; Weight)
J 26(1): 83 (hierarchy in coho salmon fry)
(1): 165 (gill dimensions re fishes size)
(3): 479 (effects of size-selective mortality & sampling bias on growth, mortality, production, & yield estimates)
(3): 543 (variations re polyteny of *Pseudocalanus* in Ogac L., N.W.T.)
(5): 1205 (changes in exploited American plaice stock)
(9): 2339 (& age of female shiner perch re embryo number & size)
(10): 2561 (of white whale body)
(10): 2754 (& age of steelhead trout, Babine R., B.C.)
(12): 3133 (of cod in fishery off SW Nfld.)
B 171 (average & record, of B.C. marine mammals)
T 105 (B.C. commercial groundfishes)
107 (definition of commercial, for sablefish)
113 (composition & length–weight data, Pac. ocean perch)
121 (computer program for analysis of feeding heterogeneities re predator body size)
S 1282 (recent changes in composition Canadian Atl. swordfish catches)
1316 (& age & recruitment comparisons for Scotian Shelf haddock)
S 1345 (particulate matter retention by screens & filters)
A 138 (queen crab, at maturity & in different areas)

Skate, barndoor (*Raja laevis*)
S 1325 (biosynthesis of 1α-hydroxycorticosterone by)

Skate, little (*Raja erinacea*)
S 1325 (biosynthesis of 1α-hydroxycorticosterone by)

Skate, thorny (*Raja radiata*)
J 26(4): 805 (parasites, Nfld.)
S 1308 (blood plasma binding of steroids)
1313 (steroids in body fluids)

Skate, winter (*Raja ocellata*)
S 1325 (biosynthesis of 1α-hydroxycorticosterone by)

Skates (Atlantic)
A 124 (use for fish protein concentrate)

Skeena River System, B.C. (*see also* Babine Lake; *also* Pacific salmon species)
T 133 (scale characteristics of sockeye salmon from nurseries)
S 1271 (population biology factors of sockeye salmon)

Skelding, J.
S 1303 (marine sediment decomposition)

Skeleton (*see also* Osteology)
J 26(1): 175 (re identifying northern pike vs. maskinonge)
(9): 2431 (geographical variations in brook stickleback)
(10): 2561 (vertebrae & ribs weight in white whales)
T 123 (clearing & staining young Pac. salmons for study of)

Skin (*see also* Pigment; Scales)
J 26(5): 1185 (ultraviolet-absorbing & -fluorescing substances in coho salmon belly)
(7): 1927 (silvering by purines of freshwater fishes)

Skototaxis
J 26(2): 279 (re benthic invertebrates river stream movements)

Skull (*see* Osteology; Otoliths)

Small, Lawrence Frederick
J 26(1): 145 (marine organisms zinc requirements)

Smelt, American (*Osmerus mordax*)
J 26(3): 597(F) (retinal structure re activity, etc.)
B 151(F) (smoking; sausage products; canned smoked)

Smith, Charlie Edward
J 26(1): 111 (coho folic acid anemia)

Smith, Janice Elaine
T 131 (B.C. trawl fishery 1968)

Smith, Howard Donald
T 133 (sockeye scale characteristics)
S 1296 (population estimates of salmon smolts)

Smith, Jim Ross
J 26(11): 3083 (detecting device for magnetized wire tags in migrating salmon)

Smith, Lynwood Stephen
J 26(1): 115 (endotoxins in salmonids)

Smith, Michael Stuart
T 113, 132 (*G. B. Reed* groundfish cruise 69-1, 69-2)

Smith, Morden Whitney
J 26(12): 3101 (natural lake changes after fertilization)

Smoking
B 151(F) (freshwater fishes)
169 : 138 (& canned smoked Pac. oyster, B.C.)

Smolt (*see* Salmon, Atlantic; *also* species of Pacific salmons; *also* species of trouts)

Snail, moon (Atlantic) (*Lunatia heros*)
J 26(3): 701 (mortality from unusually low P.E.I. estuarine salinity)

Snail, moon (Pacific) (*Polinices lewisi*)
B 168 : 31 (toxicity tests in B.C.)

Snakeblenny, fourline (*Eumesogrammus praecisus*)
J 26(3): 597(F) (retinal structure re activity, etc.)

Sodium compounds (*see also* Salt)
J 26(2): 413 (cation concentration in Atl. salmon semen)
T 114 (content of Atl. & Pac. herrings meals)
S 1273 (partial molal volumes of chloride, sulphate, bicarbonate, & nitrate in sea water)

Sole, butter (*Isopsetta isolepsis*)
CNS 28 (B.C. commercial landings for animal feed)
T 105 (life history, feed, etc.)

Sole, Dover (*Microstomus pacificus*)
J 26(8): 1985 (stock & yield forecast, N Pac. Ocean)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 117, 131 (B.C. commercial trawl landings, 1968)
132 (catches in B.C. experimental trawling, 1969)

Sole, English (*Parophrys vetulus*) (lemon sole)
J 26(8): 2215 (pathology of *Glugea hertwigi* microspordial infection)
(9): 2319 (parasites, B.C.)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 105 (life history, feed, etc.)
117, 131 (B.C. commercial trawl landings, 1968)
135 (length–weight relations)
S 1319 (tagging results, B.C. waters)

Sole, flathead (*Hippoglossoides elassodon*)
J 26(8): 1985 (stock & yield forecast, N Pac. Ocean)
T 100 (embryonic development)

Sole, lemon (Pacific) (*see* Sole, English)

Sole, petrale (*Eopsetta jordani*) (Pacific brill)
J 26(10): 2651 (EDTA effect on fillet spoilage characteristics)
CNS 28 (Canadian & American trawlings off B.C. 1954–65)
T 105 (life history, feed, etc.)
117, 131 (B.C. commercial trawl landings, 1968)
135 (length–weight relations)

Sole, rex (*Glyptocephalus zachirus*)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 117 : 131 (B.C. commercial trawl landings, 1968)
132 (catches in B.C. experimental trawling)

Sole, rock (*Lepidopsetta bilineata*)
J 26(8): 1985 (stock & yield forecast, N Pac. Ocean)
(9): 2319 (parasites, B.C.)
CNS 28 (Canadian & American trawlings off B.C., 1954–65)
T 105 (life history, feed, etc.)
108 (population studies, B.C.)
117, 131 (B.C. commercial trawl landings, 1968)
135 (length–weight relations)

Sole, yellowfin (*Limanda aspera*)
J 26(8): 1985 (stock size & yield forecast, NE Pac.)
T 109 (age & growth, Hecate Strait, B.C.)

Somniosus microcephalus (*see* Shark, Greenland)

Sound, reaction to
J 26(5): 1113 (auditory masking & critical band in Atl. cod)
T 102 (observed from cubmarine)
A 136 (observed from cubmarine)

Sound, ultrasonic (*see* Ultrasonic)

South America
J 26(4): 717 (*Diphyllobothrium* tapeworm & other parasites, Peru coastal area)
(4): 753 (digenetic trematodes from fishes, Argentina)

South Bay, Lake Huron, Ont.
J 26(9): 2413 (planted lake trout survival)

Spawning (*see also* Eggs, fish; Fecundity; Life history; Migration; etc.; *also* names of species)
J 26(2): 229 (artificial channels for Babine L. sockeye salmon)
(2): 473 (mailed sculpin, Gulf of Maine)
(3): 655 (variance components in estimating Bristol Bay sockeye potential)
(6): 1585 (time differences between 2 Nfld. populations of landlocked Atl. salmon)
(6): 1661 (repeated spawning effect on Atl. salmon scales)
(7): 1889 (otolith nuclei similarity re distinguishing Atl. herring spring vs. autumn spawners)
(8): 2061 (behaviour of blackspotted stickleback)
(12): 3133 (time, cod off SW Nfld.)
(12): 3252 (behaviour, western brook lamprey)
(12): 3248 (swordfish: probable W Atl. area)
B 169 : 28 (Pac. oyster, B.C.)
T 88 (Atl. herring re Bay of Fundy hydrography)
111 (pink & sockeye salmon re spawn collection)
136 (swordfish: probable W Atl. area)
S 1318 (W Nfld. cod stock)

Speciation (*see also* Taxonomy)
J 26(1): 175 (distinguishing between northern pike & muskellunge remains)
(2): 221 (distinguishing *Dugesia lugubris* from *Cura foremanii*)
(4): 741 (problems re *Schistocephalus* cestode)
(4): 1063 (*Diclidophora* monogenetic gill-parasitic trematodes re gadid hosts)
(12): 3183 (uncertain, of red vs. black threespine sticklebacks)

Species, indicator (*see* Indicator species)

Species, introduced (*see also* Transplantation)
J 26(2): 221 (European triclad turbellarian found in St. Lawrence R.)
B 169 : 159 (oyster drills from Atl. & Japanese oysters transplanted into B.C.)

Species, new (*see also* Family, new; Genera, new)
J 26(2): 311 (*Clavellomimus macruri* parasitic copepod)
(4): 753 (10 strigeoid digenetic trematodes from S American fishes)
(4): 787 (& genera, of 3 Australian fishes hemiurid trematodes)
(4): 799 (*Lepidophyllum cameroni* digenetic trematode, B.C.)
(4): 865 (*Pellucidhaptor catostomi* & *P. nasalis* trematodes from suckers)
(4): 947 (*Diphyllobothrium cameroni* cestode from monk seal)
(4): 957(F) (*Opegaster cameroni* trematode from Californian fishes)
(4): 965 (*Acanthosentis cameroni* acanthocephalan from an India fish)
(4): 997 (*Ergasilus arthrosis* parasitic copepod)
(4): 1037(F) (*Mustelicola woodsholei* new cestode genus)
(4): 1075 (*Haemogregarina mavori* hematozoan Protozoa)
(4): 1103 (*Capillaria thomascameroni* nematode from Australian bird)
(5): 1237 (*Acantholiparis caecus* off N Oregon coast)
(8): 2231 (5 bivalve species from NE Pac. Ocean)
(10): 2595 (*Acrocirrus trisectus* & *Macrochaeta pege* polychaetes)
(11): 3044 (*Chondracanthus narium* parasitic copepod)
B 170 (33 species of N American chironomids)
S 1301 (*Praecidochondria galatheae* parasitic copepod)
1306 (*Shiinoa occlusa* parasitic copepod)
1307 (4 lernaeopodid copepods parasitic on Australian fishes)

Species, new records or range extensions of (*see also* Transplantation)
J 26(2): 221 (*Dugesia lugubris* European turbellarian in St. Lawrence R.)
(2): 311 (*Lernaeopodina longibranchia* parasitic copepod new to Canada)
(2): 325 (S Alta. fishes)
(2): 460 (Nfld. blackspotted stickleback E range extension)
(2): 469 (shortnose greeneye NE range extension, N.S.)
(3): 709 (first P.E.I. northern redbelly dace)
(4): 1075 (various haematozoan Protozoa)
(5): 1237 (spinycheek liparid, S to Oreg. coast)
(5): 1371 (N range extension, California whitefish & ocean halibut)
(5): 1375 (first Massachusetts Bay arctic shanny record)
(6): 1680 (deepsea cusk-eel E to Oreg. coast)
(7): 1955 (flag rockfish westward to Aleutian Is.)
(10): 2691 (mesopelagic & other fishes, Gulf of St. Lawrence & N.S. banks)
(10): 2769 (*Ariomma bondi* first Canadian record; bigeye scad & blue runner first Gulf of St. Lawrence records)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

(11): 3088 (*Manayunkia aestuarina* extension to N America)
(12): 3246 (first B.C. black hagfish)
B 170 (distributional, of 18 N American chironomid species)
171 (B.C. cetaceans & pinnipeds)

Specific gravity (*see* Density)

Speed of swimming (*see* Swimming)

Sperm (*see* Semen)

Spines, fin (*see* Fins)

Spirochate
B 169 : 20 (*Cristispira* associated with Pac. oyster crystalline style)

Spirogyra (algae)
J 26(12): 3101 (blooms after fertilization of a lake)

Spirontocaris (hyppolytid shrimps)
J 26(7): 1899 (*S. phippsi* & *S. spinus* in W Canadian Arctic)

Spirula (cephalopods)
S 1237 (of Canada)

Spisula falcata (*see* Clam, hooked surf)

Spoilage (*see* Preservatives; Quality of fishery products)

Sponge, boring (*Cliona celata*)
B 169 : 154 (predator of Pac. oyster in B.C.)

Sporozoa
J 26(4): 725 (review, taxonomy, life cycles, in fishes)
(8): 2215 (*Glugea hertwigi* infection of English sole)

Sport fishery (*see* Angling; Salmon; Trout)

Sprague, John Booty
S 1276, 1277 (toxicity of kraft mill effluent to lobsters & salmon)
1278 (kraft pulp mill effluent for 2 aquatic animals)
1291 (NTA protects fish from copper and zinc)

Squalene
S 1286 (content of eulachon lipids)

Squalus acanthias (*see* Dogfish, spiny (Atlantic))
suckleyi (*see* Dogfish, spiny (Pacific))

Squid (*Lolliguncula brevis*)
J 26(6): 1676 (pen length re mantle length & total volume)

Squid, longfinned (*Loligo pealeii*)
T 103, 122 (in experimental Atl. otter trawlings, 1967 & 1968)

Squid, shortfinned (*Illex illecebrosus*)
T 103, 122 (in experimental otter trawlings, 1967 & 1968)
A 119 (ICNAF 1967 Canadian research report on)

Squids
S 1327 (Canadian, with synopsis)

Squires, Hubert Jacob
J 26(7): 1899 (decapod Crustacea of Beaufort Sea)
S 1311 (NW Atl. decapod Crustacea)

St. Andrews Biological Station, N.B.
MSP 12 (brochure on facilities for visiting scientists)

Stains
J 26(3): 707 (2 modified, for oyster tissue pathology)
T 123 (for young Pac. salmons skeletal studies)

Stannius, corpuscles of
J 26(3): 639 (re American eel renal physiology)

Starfish, common (*Asterias vulgaris*)
J 26(3): 701 (mass mortality due to abnormally low estuarial salinity, P.E.I.)
A 133 (calorific content as cod feed)

Starfish, leather (*Dermasterias imbricata*)
B 169 : 162 (Pac. oyster predator, B.C.)

Starfish, mottled (*Evasterias troschelii*)
B 169 : 161 (Pac. oyster predator, B.C.)

Starfish, ochre (*Pisaster echraceus*)
B 169 : 161 (Pac. oyster predator, B.C.)

Starfish, pink (*Pisaster brevispinus*)
B 169 : 161 (Pac. oyster predator, B.C.)

Starfish, sun (*Pycnopodia helianthodes*)
B 169 : 161 (Pac. oyster predator, B.C.)

Starvation (*see also* Stress)
J 26(12): 3209 (re DDT effect on rainbow trout hepatic dehydrogenase)

Steele, Donald Harold
J 26(3): 683 (additional comments on *Anonyx*)

Stennella (dolphin)
B 171 : 15 (B.C. records; taxonomy uncertain)

Stenobranchius (*Lampanyctus*) *leucopsarus* (*see* Lanternfish, smallfin)

Stenodus leucichthys (*see* Inconnu)

Stenotomus chrysops (*see* Scup)

Stephan, Charles Eugene
J 26(9): 2449 (toxicity of copper to minnows)

Stephens, Kenneth Valentine Cory
T 110 (Strait of Georgia biological oceanographic observations)
S 1326 (allochthonous bacteria and organic materials)
1355 (NE Pac. Ocean nitrate)

Steroids; Sterones (*see also* Cortisol; Hormones)
J 26(7): 1823 (1α-hydroxycorticosterone assay by sodium transport across toad bladder)
S 1308 (testosterone, 1α-hydroxycorticosterone & cortisol binding by fishes plasma proteins)
1313 (testosterone & 1α-hydroxycorticosterone in body fluids of thorny skate)
1325 (biosynthesis of 1α-hydroxycorticosterone by 4 skate species)
1329 (conversion of a C-21 to a C-19 steroid by scallop gonadal enzyme in vitro)
1340 (adult sockeye salmon interrenal activity suppression by dexamethasone corticosteroid injection)

Sterols; Sterol esters (*see also* Cortisol; Steroids)
S 1264 (cholesterol, desmosterol, & other sterols in king crab & queen crab)

Stew
B 169 : 139 (canned Pac. oyster)

Stewart, James Edward
J 26(1): 1 (*Gaffkya homari* in lobster)
(5): 1385 (lobster disease gaffkemia)
(5): 1392 (lobster hemolymph)
(9): 2503 (effects of temperature on gaffkemia)
S 1288 (study of lobster using serum protein concentration)
1344 (gaffkemia in lobsters)

Stichaeus punctatus (*see* Shanny, arctic)

Stickleback, blackspotted (*Gasterosteus wheatlandi*) (twospine stickleback)
J 26(2): 460 (E range extension, Nfld.)
(5): 1390 (distribution, Sable Is., N.S.)
(8): 2061 (reproductive behaviour)

Stickleback, brook (*Culaea inconstans*) (*Eucalia inconstans*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(7): 1927 (purine sources of skin silvering)
(9): 2431 (geographic variation; distribution; nomenclature)

Stickleback, fourspine (*Alpeltes quadracus*)
J 26(4): 975 (*Bothrimonus* cestode biology in)
(5): 1390 (distribution, Sable Is., N.S.)

Stickleback, ninespine (*Pungitius pungitius*)
J 26(5): 1391 (distribution, Sable Is., N.S.)

Stickleback, threespine (*Gasterosteus aculeatus*)
J 26(2): 405 (4 phenotypic variations, Alaska)
(4): 741 (experimental infection with *Schistocephalus solidus* cestode)
(9): 2319 (parasites, B.C.)
(12): 3183 (predation & evolution; pigmentation, etc.)

Stickleback, twospine (*see* Stickleback, blackspotted)

Stizostedion canadense (*see* Sauger)
vitreum vitreum (*see* Walleye)

St. Lawrence, Gulf of (*see also* Hydrography; Oceanography)
J 26(5): 1205 (exploitation effects on Magdalen Shallows American plaice stock)
(5): 1273 (comparison of cod & haddock feed)
(7): 1889 (otolith nuclei similarity in spring & autumn spawning herring)
(10): 2691 (mesopelagic & other fishes)
T 139 (catch statistics, age, & length composition, of herring)
S 1353 (sediments mineralogical composition)

Stocks (*see also* Mortality; Populations; Recruitment; *also* names of organisms)
J 26(5): 1205 (exploitation effects on American plaice)
(6): 1605 (reduction of zooplankton standing stocks in a lake by predaceous *Cyclops*)
(7): 1699 (native vs. introduced brook trout throughout world)
(8): 1985 (analytical approach to size, NE Pac. Ocean demersal fishing)
(10): 2715 (stock recruitment systems re environmental fluctuations effects)
(12): 3133 (SW Nfld. cod)
CJG 16 (distribution & migration of Nfld. herring, 1967–68)
T 92 (computer program for equilibrium yield per recruitment to a fish stock)
134 (parasitic indicator species, for Atl. salmon)
S 1302 (chum salmon N American & Asian)
1318 (biology & fishery of W Nfld. cod)

Stoddard, Judith Helen
T 79 (fat contents of Canadian Atl. herring)

Stolzenberg, Ernest William
CNS 27 (age composition of 1965 B.C. sockeye, chum, & pink salmon)

Stomach (*see also* Digestion; Feed)
J 26(1): 1 (lobster gastric secretion as defense against *Gaffkya homari* infection)
(10): 2561 (weight in white whales)

Stomach contents (*see* Feed)

Stomias boa ferox (*see* Dragonfish, boa)

Stonecat (*Noturus flavus*)
J 26(6): 1439 (distribution in Canadian Missouri R. headwaters)

Stoneflies (*see* Plecoptera)

Storage (for cold storage, *see* Refrigeration)
B 169 : 109 (of live & shucked Pac. oysters)
A 138 (queen crab)

Storms
J 26(8): 2223 (rate of growth effect on subsequent ocean surge elevations)

Strait of ... (*see* name of strait)

Strasdine, George Alfred
S 1270 (amylopectin accumulation in *Clostridium botulinum*)

Stress (*see also* Activity)
J 26(1): 63 (effects of hypoxial in coho salmon eggs & fry)
S 1340 (re interrenal activity suppression in sexually maturing sockeye salmon)

Strigeatoidea (*see* Trematodes)

Strongylocentrotus franciscanus (*see* Sea urchins)

Stunkard, Horace Wesley
J 26(4): 725 (Sporozoa re fishes inspections)

Style, crystalline
B 169 : 20 (function, & *Cristispira* spirochaete, in Pac. oyster)

Subba Rao, Durvasula Venkata
J 26(6): 1625 (extraction of chlorophylls: correction on J26(8): 2264)

Submarine
T 102 (equipment & observations from cubmarine)
A 136 (observations from, and possibilities of cubmarine)

Sucker, longnose (*Catostomus catostomus*)
J 26(2): 325 (S Alta. distribution)
(4): 865 (new monogenetic trematode species from nasal cavity)
(5): 1289 (age, growth, & maturity, W L. Superior)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Sucker, northern mountain (*Catostomus platyrhynchus*) (*Pantosteus platyrhynchus*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Sucker, quillback (*Carpiodes cyprinus*) (Quillback)
J 26(2): 325 (S Alta. distribution)

Sucker, white (*Catostomus commersoni*)
J 26(2): 325 (S Alta. distribution)
(3): 633 (aging from scales vs. fin rays)
(4): 865 (new monogenetic trematode species from nasal cavity)
(5): 1368 (fluorescence of white muscle nucleotides)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(10): 2643 (oxygen metabolism re body weight)
(10): 2681 (shape & structure re selectivity of gillnets)
(12): 3266 (diel activity, judged by gillnet catchability)
B 151(F) (smoking; canning)

Sulphur compounds
J 26(7): 1763 (hydrogen sulphide in B.C. meromictic lakes)
(12): 3254 (dimethyl sulphoxide suitable extender for freezing salmon sperm)
T 114 (content of Atl. & Pac. herring meals)

Sunfish, bluegill (*see* Bluegill)

Superior, Lake (*see also* Great Lakes)
J 26(5): 1289 (longnose sucker age, growth, maturity)

Surges, oceanic
J 26(8): 2223 (rate of storm growth effect on subsequent elevations)

Survey (*see* Exploration)

Survival (*see also* Life history; Lethal limits; Mortality; Predation; *also* names of species)
J 26(1): 133 (fry trap for estimating salmonid egg-to-fry)
(2): 229 (Babine L. sockeye salmon fry, from natural vs. artificial stream rearing)
(2): 389 (temperature & salinity effects on Dungeness crab larvae)
(5): 1227 (discarded American plaice)
(5): 1263 (finclipping effect on sockeye salmon)

(6): 1473 (overwinter, of wild brook trout fingerlings)
(6): 1619 (effect of fluorescent pigment vs. finclipping on coho salmon fry)
(7): 1867 (of wild vs. hatchery-reared young Atl. salmon)
(7): 1931 (lobster larvae unaffected by bleached kraft mill effluent)
(9): 2283 (of 5 haustoriid amphipod species to 4 environmental factors)
(9): 2413 (planted lake trout, South Bay, L. Huron)
T 88 (Atl. herring larvae re Bay of Fundy hydrography)

Suryanarayana Rao, S. V.
J 26(3): 704 (canned shrimp compounds)

Sutcliffe, William Humphrey, Jr.
S 1345 (marine particles retention)

Swim bladder (*see* Bladder, swim)

Swimming; Swimming speed (*see also* Bladder, swim; Buoyancy)
J 27(2): 361 (of 3 Haustoriidae amphipod species)
(5): 1383 (thrust of sockeye salmon re gillnet mesh selectivity)
(6): 1429 (re stream fishes ecology)
(6): 1647 (sustained ability of walleye & yellow perch larvae)
(11): 2807 (speed of *Tilapia nilotica* re oxygen consumption & salinity)
A 118 (sockeye salmon metabolism for)

Swordfish (*Xiphias gladius*)
J 26(6): 1597 (nucleotide degradation in frozen muscle)
(12): 3248 (larval, from 3 localities in W Atl., re probable spawning area)
T 136 (origin & distribution of larval, in W Atl.)
S 1282 (recent changes in size composition of Canadian Atl. catches)
A 119 (ICNAF 1967 Canadian research report on)
120 (longline lures for)
131(F) (life cycle; fishery)

Symbolophorus veranyi (*see* Lanternfish, large-scale)

Symons, Philip Edward Kyrle
J 26(7): 1867 (dispersal of juvenile Atl. salmon)

Sympatry
J 26(10): 2659 (of 3 oligochaete species re nutritional resources in sediments)
(12): 3183 (of different coloured three-spine sticklebacks)

Synchaeta tamara (*see* Rotifera)

Syndesmis franciscana (rhabdocoel turbellarian)
J 26(10): 2669 (parasitic in sea urchin, & nonsynonymy with *S. antillarium*)

Syngnathus griseolineatus (*see* Pipefish, bay)

Synonymy (*see* Nomenclature; Taxonomy)

Systematics (*see* Phylogeny; Speciation; Taxonomy)

Szidat, Lothar
J 26(4): 753 (structure, development, & behaviour of new strigeatoid metacariae)

T

Tagging methods, returns, losses, and interpretation (*see also* Marking; Migration)
J 26(2): 269 (re NW Miramichi R., N.B., salmon contribution to other Maritimes fishery areas)
(5): 1301 (Nfld. American plaice)
(8): 2201 (white whales in Canadian Arctic)
(11): 3083 (detecting devices for magnetized wire tags on coho salmon)
T 107 (for identifying sablefish reared in tanks)
S 1296 (aluminum staple tag for salmon smolts)
1302 (chum salmon re origin, open N Pac.)
1319 (English sole: results from B.C. tagging)
A 123 : 358 (Nfld. salmon)
138 (queen crab)

Tanichthys albonubes (*see* Minnow, White Cloud Mountain)

Tank
J 26(7): 1956 (experimental to simulate reservoir conditions)
(8): 2227 (experimental, to simulate rapids environment)
T 107 (for sablefish culture)

Tanypleuris alcicornis (parasitic copepod)
J 26(6): 1407 (first Canadian record, & assignment to new family Tanypleuridae)

Tanypodinae
T 124 (classification of Nearctic)

Tapeworms (*see* Cestoda)

Tarr, Hugh Lewis Aubrey
S 1289 (biosynthesis of inosinic and uridylic acids)
A 130 (preservation problems of fish muscle)

Taste (*see* Flavour; Quality)

Taste, reaction to
J 26(3): 583 (Atl. cod re fish vs. stale feed)

Tautogolabrus adspersus (*see* Cunner)

Tautz, Arthur
J 26(10): 2715 (simulated long-term environmental fluctuations on maximum sustained yield)

Taxonomy; Synonymy; Systematics (*see also* Nomenclature; Speciation)
J 26(2): 311 (revision of Clavellinae parasitic copepods)
(3): 683 (arctic & Atl. N American *Anonyx* amphipods)
(4): 725 (Sporozoa re fish infections)
(4): 741 (*Schistocephalus solidus* cestode)
(4): 753 (strigeatoid digenetic trematodes from S American fishes)
(4): 799 (*Lepidophyllum* monogenetic trematodes)
(4): 849 (*Cystidicola* nematodes from fish swim bladders)
(4): 975 (*Bothrimonus* cestode genus)
(4): 997 (*Ergasilus* parasitic copepods)
(4): 1013 (*Caligus elongatus* parasitic copepod re *C. rapax*)
(6): 1407 (Tanypleuridae: new family of caligoid Copepoda)
(7): 1727 (Wash. & S B.C. Ophiuroidea)
(10): 2595 (new family of Polychaeta Sedentaria)
(10): 2669 (nonsynonymy of *Syndesmis franciscana* & *S. antillarium* turbellarian)
(11): 2987 (revision of *Salmincola* copepod genus)
(12): 3279 (*Haploscoloplos* vs. *Scoloplos* oligochaetes; synonymy of *S. acutus* & *S. armiger*)
B 169 : 3 (B.C. oysters)
170 (N American chironomids, including 33 new species)
T 124 (classification of Nearctic Chironomidae)
S 1263 (*Caligus* copepods)

Tedla, Shibru
J 26(4): 833 (yellow perch parasites)

Tellina agilis (Atlantic pelecypod)
J 26(3): 701 (severe mortality due to unusually low P.E.I. estuarine salinity)

Telmatogetoninae
T124 (classification of Nearctic)

Temperature, reactions to (*see also* Lethal limits)
J 26(1): 93 (temperature-acclimated Atl. salmon activity & respiration as affected by temperature changes)
(2): 389 (Dungeness crab larvae growth & survival)
(2): 461 (in vitro cultured rainbow trout ovary cells)
(7): 1813 (re bluegill sunfish endogenous nitrogen excretion)
(8): 2093 (re Atl. salmon parr & smolt buoyancy)
(9): 2283 (5 haustoriid amphipod species)
(9): 2363 (re growth rate & body composition of young sockeye salmon)
(9): 2493 (re lead effect on brook trout growth)
(9): 2503 (re lobster susceptibilty to gaffkemia)
(9): 2517 (of Pac. halibut re rabbit, as caused by temperature effect on dehydrogenase enzyme activity)
(12): 3133 (bottom, re SW Nfld. cod growth, etc.)

Temperature control (*see* Thermostat)

Temperature of natural waters (*see also* Hydrography; Limnology; Oceanography; *also* names of lakes, rivers, etc.)
J 26(2): 399 (deforestation effects on stream)
(10): 2746 (1968 in and off Gulf of Maine)
(12): 3248 (re swordfish spawning, W Atl.)
T 120 (Bedford Basin, N.S.)
136 (re swordfish spawning, W Atl.)
S 1280 (St. John's–Flemish Cap section, Nfld.)

Templeman, Wilfred
S 1280 (St. John's–Flemish Cap temperatures & salinities)
1317 (distribution & characteristics of Atl. salmon)
A 119 (ICNAF area researches 1967)
137 (importance of groundfish)

Teredo navalis (*see* Shipworms)

Terns
J 26(4): 1103 (nematodes & other helminths from Australian)

Territorialism
J 26(1): 82 (hypoxially stressed coho salmon fry behaviour)
(6): 1429 (re stream fishes ecology)
S 1334 (re production limitations in salmonid stream populations)

Testes
J 26(5): 1146 (castration effects on adult sockeye salmon pituitary cytology)
(9): 2521 (re lake whitefish hermaphroditism)
(11): 2975 (re interrenal tissue hypertrophy of sexually maturing sockeye salmon)

S 1289 (de novo biosynthesis of inosinic & uridylic acids in Pac. salmon & rainbow trout)
1292, 1336 (goldfish spermatogenesis restored by salmon pituitary extract)
1338 (androgens effect on cortisol distribution & secretion in castrated sockeye salmon)

Testosterone (*see* Hormones; Steroids)

Tetrachloro-*o*-benzoquinone (*see* Pollution)

Tetracyline (*see* Antibiotics)

Texture (*see* Quality of fishery products)

Thalassiosira nordenskioldii (a phytoplankter)
J 26(6): 1625 (chlorophylls extraction procedure)

Thaleichthys pacificus (*see* Eulachon)

Thawing (*see also* Freezing; Refrigeration)
J 26(12): 3217 (of fish frozen whole or gutted at sea)

Theragra chalcogrammus (*see* Pollock, walleye)

Thermostat
J 26(1): 154 (precise temperature control system for low-temperature fish refrigeration)

Thiamin (*see* Vitamin B group)

Thomas, Gethin
J 26(10): 2769 (first records of *Ariamma bondi*, *Caranx crysos*, & *Selar crumenopthalmus* in Gulf of St. Lawrence)

Thomas, Martin Lewis Hall
J 26(3): 701 (mass mortality of fauna, Bideford R., P.E.I.)
(5): 1121 (*Urosalpinx* distribution & importance)
T 119 (anti-fouling paints & wood preservatives)

Thomas, William Hewitt
J 26(5): 1133 (phytoplankton nutrient enrichment)

Thompson, Bruce Hunter
J 26(4): 871 (*Diphyllobothrium* in trout)

Thomson, John Arthur Collingwood
J 26(1): 123 (weight–length regression model)
T 92 (A 1130 FORTRAN version of FRG 708)
94–97 (Nfld. herring sampling data 1964–68)
108 (studies on rock sole)
112 (multiple discriminant analysis (FORTRAN 1130) extended version)
127 (N Pac. Ocean surface transport charts, 1968)
128 (N Pac. Ocean Ekman transport, 1946–68)
135 (groundfish length–weight relationships)

Threlfall, William
J 26(4): 805 (parasites from Nfld. elasmobranchs)

Thrombocytes (*see* Blood)

Thymallus arcticus (*see* Grayling, arctic)

Thysanoëssa spinifera (*see* Euphausids)

Thysanote gymnobranchiata (parasitic copepod)
S 1307 (new species, from Australian fishes)

Tibbo, Simeon Noel
J 26(12): 3248 (larval swordfish from W Atl.)
T 136 (larval swordfish in W Atl.)
139 (Gulf. of St. Lawrence herring catch statistics)
S 1282 (swordfish catches size composition changes)
A 131(F) (swordfish)

Tides (*see also* Oceanography)
J 26(9): 2477; (11): 2775 (tidal barriers effect on Bay of Fundy M_2 tide, re tidal power projects)
(11): 2887 (theory of tidal energy exploitation re Bay of Fundy)
S 1341 (re eutrophication of inlet extension of Victoria harbour, B.C.)

Tilapia nilotica
J 26(11): 2807 (oxygen consumption re swimming speed & salinity)

Tin compounds
T 119 (for anti-fouling paints for ships hulls)
A 121 (for protecting lobster traps from shipworms)

Tintinnidae
J 26(6): 1485 (*Ptychocylis obtusa* ecology, Ogac L., Baffin Is.)

Toad (*Bufo marinus*)
J 26(7): 1823 (sodium transport across bladder as 1α-hydroxycorticosterone assay method)

Tolerance (*see also* Lethal limits; *also* factors involving tolerance reactions, e.g. Desiccation; Oxygen, dissolved; Salinity; Temperature)

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J 26(9): 2283 (of 5 haustoriid amphipod species to 5 environmental factors)
A 138 (of queen crab to environment)

Tomcod, Atlantic (*Microgadus tomcod*)
J 26(4): 975 (*Bothrimonus* cestode biology in)

Tomlinson, Neil
CVG 41 (weight changes in Pac. coast fish stored at sea)
43, 44 (storage of Pac. salmon at sea)

Toronto harbour, Ont.
J 26(10): 2659 (nutritional resources of 3 oligochaete species in sediments)

Toxicants; Toxicity; Toxins (*see also* Herbicides; Insecticides; Paralytic shellfish poison; Pesticides; Piscicides; Pollution)
J 26(1): 115 (coho salmon & rainbow trout resistance to bacterial endotoxins)
(8): 2208 (moray eel ciguatoxin activity re anticholinesterase action)
(9): 2449 (chronic toxicity of fathead minnow to copper)
(9): 2493 (lead effect on brook trout growth)
(11): 3055 (of tetrachloro-*o*-benzoquinone in kraft mill effluent toward young Atl. salmon)
B 169, 169: 151 (paralytic shellfish poisoning toxicity & detoxification, B.C.)
S 1276–1278 (kraft mill effluent, to lobster & Atl. salmon)

Trachurus trachurus (*see* Mackerel, horse)

Tracking
J 26(8): 2173 (white bass by ultrasonic transmitter in stomachs)

Transferrins
J 26(5): 1397 (distribution of groups in harp seal blood serum)
(9): 2351 (of Pac. halibut serum)
(12): 3268 (variants in Pac. hake)

Transformation (*see* Metamorphosis)

Transplantation (*see also* Species, introduced)
J 26(2): 325 (kokanee salmon & various trouts into Alta.)
(7): 1699 (world distribution of introduced brown trout)
CJG 16 : 22 (1968 returns from 1966 pink salmon egg transplantation to Nfld. from B.C.)
16 : 24 (results of oyster, from P.E.I. to Nfld.)
A 119, 123: 348 (pink salmon to Nfld.)

Transport, mass (of waters) (*see also* Currents, marine; Oceanography)
T 126 (computations for N Pac. Ocean, 1968)
127 (surface charts, N Pac Ocean, 1968)
128 (computation of Ekman, N Pac. Ocean, 1946–68)

Transportation
A 138 (queen crab)

Traps
J 26(1): 133 (for estimating salmonid fry survival)
(2): 279 (for river benthic invertebrates)
(6): 1685 (for collecting emerging stream insects)
CNG 87 (experimental B.C. prawn trap fishing)
A 121 (treating lobster, against shipworm attack)
128 (condensed version of CNG 87 above)
138 (vessels & types of traps for queen crab fishery)

Trawl; Trawling
J 26(10): 2751 (bottom sediment sampler attached to trawl board)
CNS 28 (Canadian & American production from grounds off B.C., 1954–65)
T 86 (Canadian catches of cod & haddock on Scotian Shelf & Georges Bank, 1965)
102 : 12, 23 (underwater observations from submarine)
103, 122 (lists of invertebrates & fishes taken in Atl. otter-trawl surveys, 1967 & 1968)
113, 132 (research cruises, B.C., 1969)
117, 131 (catch & effort statistics in B.C. fishery, 1968)
125 (engineering performance data on Canadian E coast groundfish otter trawls)
S 1279 (comparison of catches by two research vessels trawling together off S Labrador)
1318 (fishery for cod off W Nfld.)
A 136 (underwater observations from submarine)

Trematoda (flukes)
J 26(4): 753 (description of metacercaria of 18 species (10 new) of strigeatoid digenetic, from S America)
(4): 787 (3 new genera species of hemiurid, from Australian fishes)
(4): 799 (*Lepidophyllum cameroni* new species from red Irish lord, B.C.)
(4): 805 (mono- & digenetic, of Nfld. fishes)
(4): 813 (3 species from early sea life pink salmon)
(4): 833 (mono- & digenetic, in Bay of Quinte yellow perch)
(4): 845 (*Anenterotrema* spp. nutrition modes)
(4): 865 (*Pellucidhaptor catostomi* & *P. nasalis*, new species)
(4): 879 (in Atl. argentine, & use as biological indicators)
(4): 893 (biology of *Tubulovesicula lindbergi* & *Lecithaster gibbosus* in pink & chum salmon)

(4): 957(F) (*Opegaster cameroni* new species & *Otodistomum veliporum* from S California fishes)
(4): 1063 (*Diclidophora* speciation re gadid fish hosts speciation; *Flexiphora ophidii* description)
(9): 2319 (list of monogenetic & digenetic found in B.C. marine fishes)
T 134 (digenetic, as indicators for distinguishing Atl. salmon stocks)
S 1287 (digenetic *Lampritrema nipponicum* parasitic in Atl. argentine)

Tresus capax (*see* Clam, horse)

Triaenophorus (tapeworms)
J 26(4): 821 (*T. nodulosus* biology & infection dynamics in yellow perch, Heming L., Man.)
(4): 833 (*T. nodulosus* in yellow perch, Bay of Quinte, Ont.)
(8): 2260 (*T. crassus* in arctic lampreys, Great Slave L.)

Trichoptera (*see also* Insects, aquatic)
J 26(5): 1157 (feed, habits, ecology, in small Que. stream)
(8): 2016 (partitioning community respiration in a lake sediment)

Triclads (Turbellaria)
J 26(2): 221 (*Dugesia lugubris* found in St. Lawrence R., triclads distribution in E Ont.)

Triglops murrayi (see Sculpin, mailed)
pingeli (*see* Sculpin, ribbed)

Triglycerides (*see also* Acids, fatty; Lipids; Oils and fats)
J 26(6): 1577 (source of free fatty acids in Atl. herring oils)
(7): 1857 (lipolytic activity toward long-chain, in rainbow trout muscle)
(8): 2037 (in capelin lipids)
S 1330 (separation from free fatty acids, by a suitable chromatographic procedure)

Trigonulina hancocki (*see Verticordia hancocki*)

Trimethylamine
J 26(9): 2523 (values re quality of scallop meats chilled in ice vs. refrigerated sea water)
(10): 2651 (supression by EDTA dip for fish fillets)

Trinity Bay, Nfld.
CJG 16 (coastal capelin migrations)

Tripe, Robert Leslie King
T 106 (Ocean Station P oceanographic data time distribution)

Tropocyclops prasinus (*mexicanus*) (a copepod)
J 26(8): 2135 (horizontal distribution on L. Ontario)
(10): 2543 (vertical distribution & seasonal abundance, Parry Sound, Ont.)

Tropomyosin (*see* Myosin)

Trout (in general)
J 26(11): 2987 (parisitization by *Salmincola* copepods)
S 1334 (limitations on stream populations production)
1335 (production & genetic factors in managed populations)

Trout, brook (*Salvelinus fontinalis*) (speckled trout)
J 26(2): 325 (S Alta distribution)
(3): 695 (mass mortality & behaviour in pesticide-polluted stream)
(4): 849 (*Cystidicola* nematodes in swim bladder)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(6): 1459 (detection of infectious pancreatic necrosis virus in carriers)
(6): 1473 (wild fingerling overwinter survival)
(7): 1699 (world distribution: native or introduced)
(7): 1847 (physiological consequences of aortic catheterization)
(7): 1927 (purine sources of skin silvering)
(9): 2493 (effects of lead, temperature, & dissolved oxygen fluctuations on growth)
(10): 2643 (oxygen metabolism re body weight)
(12): 3259 (infectious pancreatic necrosis virus in hatchery-held young Atl.)
S 1291 (antipollutant agent protecting from zinc & copper)
1324 (DDT sublethal effect on nervous system)

Trout, brown (*Salmo trutta*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(8): 2165 (seasonal activity & feeding pattern re food availability)
(10): 2643 (oxygen metabolism re body weight)
(12): 3259) infectious pancreatic necrosis virus in Atl. hatchery young)
(12): 3275 (night feeding in experimental stream channel)
S 1308 (blood plasma protein binding of steroids)

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Trout, cutthroat (*Salmo clarki*)
J 26(2): 325 (S Alta. distribution)
(2): 357 (adding canthaxanthin to feed of young, to enhance flesh colour)
(5): 1243 (movements & homing of blinded & anosmic vs. normal, Yellowstone L.)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Trout, golden (*Salmo aquabonita*)
J 26(2): (transplanted into Alta.)

Trout, lake (*Salvelinus namaycush*)
J 26(2): 325 (S Alta. distribution)
(4): 843 (*Cystidicola* nematodes in swim bladder)
(4): 871 (*Diphyllobothrium* transmission to)
(9): 2413 (survival of planted, South Bay, L. Huron)
B 151(F) (smoking; canning)

Trout, rainbow (*Salmo gairdneri*) (*see also* Trout, steelhead)
J 26(1): 33 lakeward migration, Lardeau R., B.C.)
(1): 115 (metabolic effects of bacterial endotoxins)
(2): 325 (S Alta. distribution)
(2): 357 (adding canthaxanthin to feed to enhance flesh colour)
(2): 456 (upper lethal temperature uniformity in phenotypes from Great Lakes watershed streams)
(2): 461 (factors affecting in vitro cultured ovary cells)
(3): 687 (age & vision as bottom colour selection factors)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(7): 1801 (digestive response to pellet diets)
(7): 1857 (muscle lipolytic activity toward long-chain triglycerides)
(7): 1939 (uptake of dieldrin pesticide by gills)
(8): 2193 (Dylox organophosphate insecticide effect on larvae)
(8): 2237 (cryo-protective agents re muscle lipid hydrolysis)
(8): 2247; (9): 2511 (infectious pancreatic necrosis virus disease)
(9): 2311 (disinfection against *Aeromonas liquefaciens* transmission)
(12): 3209 (effect of feeding & DDT on activity of hepatic dehydrogenase)
(12): 3259 (infectious pancreatic necrosis virus in hatchery-held young Atl.)
(12): 3233 (response to overhead light, re age & intensity)
(12): 3275 (night feeding in experimental stream channel)
S 1289 (inosinic & uridylic acids de novo biosynthesis in testes & liver)
1335 (production & genetic factors in managed populations)

Trout, speckled (*see* Trout, brook)

Trout, steelhead (*Salmo gairdneri* (*see also* Trout, rainbow)
J 26(5): 1400 (cryo-preserved sperm fertilization effectiveness)
(10): 2754 (age from scales, sex ratio, & size, Babine R., B.C.)
(10): 2765 (branding young with tool cooled by liquid nitrogen)
(11): 2823 (morphological & biochemical changes in parr-to-smolt transformation)
S 1297 (enzymic degradation of egg capsule during hatching)
1305 (marine microorganisms associated with feed of young)

Trout Lake (*see* Lardeau River, B.C.)

Troutperch (*Percopsis omiscomaycus*)
J 26(2): 325 (S Alta. distribution)
(7): 1927 (purine source of skin silvering)

Truscott, Beryl
J 26(12): 3254 (improved extender for freezing Atl. salmon spermatozoa)
T 93 (freezing sperm of Atl. salmon)
S 1313 (cartilaginous fish body fluids)
1325 (1α-hydroxycorticosterone in vivo and in vitro)

Try, Kenneth
S 1266 (LDD & DDD diastereoisomers of phytanic acid)

Tsuyuki, Hiroshi
J 26(9): 2351 (halibut transferrin systems)
(10): 2633 (sablefish muscle protein polymorphism)

Tube-snout (*Aulorhynchus flavidus*)
J 26(9): 2319 (parasites, B.C.)

Tubifex tubifex (tubificid oligochaete)
J 26(10): 2659 (nutritional resources in Toronto harbour sediments)

Tubulovesicula lindbergi (hemiurid trematode)
J 26(4): 893 (biology in pink & chum salmon)

Tullibee (*see also* Herring, lake)
B 151(F) (smoking)

Tully, Christine Margaret
J 26(4): 1063 (monogean gill parasites)

Turbellaria (*see also* Triclads)
J 26(10): 2669 (*Syndesmis franciscana* parasitic in sea urchin; & nonsynonymy with *S. antillarium*)

Turbot (Pacific) (*see* Flounder, arrowtooth)

Twines
A 129 (synthetic fibres used for fishing)

Tyler, Albert Vincent
J 26(7): 1943 (anatomy of winter flounder ovary)
T 102 (1968 submersible operations observations)
116 (observations on *Clymenella torquata*)
121 (analysis of feeding heterogeneities)

U

Ultrasonics
J 26(8): 2173 (tracking method for displaced white bass)
S 1269 (high frequency for parasite detection in whitefish)

Ultraviolet radiation (*see also* Fluorescence)
T 120 (absorbance of Bedford Basin waters, N.S.)

Upogebia pugettensis (*see* Shrimp, mud)

Uridylic acid
S 1289 (biosynthesis in Pac. salmon & rainbow trout)

Urinary system
J 26(3): 639 (American eel renal physiology)

Urophycis (*see also* Hake (Atlantic))
J 26(2): 421 (cranial osteology re other Gadidae genera)

Urophycis tenuis (*see* Hake, white)

Urosalpinx cinerea (*see* Oyster drill, eastern)

Utter, Fred Madison
J 26(1): 15 (isozymes in sockeye sera)
(12): 3268 (Pac. hake transferrin variants)

V

Vanstone, William Edward
J 26(5): 1185 (salmon skin purines & pteridines)

Varga, Sandor
J 26(9): 2523 (landed scallop meat quality)

Venerupis japonica (*see* Clam, Manila)

Vertebrae
J 26(12): 3133 (count averages of cod off SW Nfld.)
T 94–97 (counts, Nfld. herring, 1964–65 to 1967–68)

Verticordia (*Haliris*) *spinosa* (septibranchid bivalve)
J 26(8): 2230 (new NE Pac. species)

Verticordia (*Trigonulina*) *hancocki* (septibranchid bivalve)
J 26(8): 2230 (new NE Pac. species)

Vessels, fishing
A 138 (types, for queen crab)

Victoria Harbour, B.C.
S 1341 (eutrophication of the Gorge & Portage Inlet)

Viperfish (*Chauliodus sloani*)
J 26(10): 2691 (new Canadian Atl. records; diurnal depth distribution)
T 103 (taken in Atl. otter trawl survey, 1967)

Virus
J 26(2): 461 (amphibian, affecting rainbow trout ovary cells)
(6): 1459; (8): 2247; (9): 2511; (12): 3259 (re infectious pancreatic necrosis, in trouts & Atl. salmon)

Vision (*see also* Eye; Light, reactions to)
J 26(1): 21 (responses of smallmouth bass to shade)
(3): 583 (re Atl. cod offered moving vs. nonmoving feed)
(3): 687 (as rainbow trout bottom colour selection factor)
(5): 1243 (homing of blinded vs. normal cutthroat trout)

Vitamin B group
J 26(1): 111 (coho salmon anemia from folic acid deficiency)
T 114 (analysis of Canadian Atl. herring meals)
A 125 (content in fish protein concentrates)

Vitamins
J 26(1): 150; (5): 1347 (for culture of calanoid copepods)
(5): 1133 (re seawater nutrient enrichment for phytoplankton growth)
T 114 (in Canadian Atl. herring meals)

W

Wagner, Harry Henry
J 26(11): 2823 (steelhead trout morphological & biochemical changes during parr–smolt change)

Wahle, Roy Joseph
J 26(5): 1263 (sockeye survival re finclipping)

Waldichuck, Michael
S 1304 (water pollution biological effects)
1341 (Vancouver Is. inlet eutrophication studies)

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Walker, Allan Giles
T 125 (otter trawl performance)

Walleye (*Stizostedion vitreum vitreum*) (yellow pickerel)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)
(6): 1647 (larvae sustained swimming ability)
(7): 1877 (maturity & fecundity in E & W L. Erie)
(7): 1927 (purine sources of skin "silvering," eye, & swim bladder silvery layer)
(12): 3266 (diel activity, judged by gillnet catchability)
B 151(F) (smoking)

Walsh, Urban Joseph
A 121 (TBTO treatment for lobster traps)

Walton, Anthony
J 26(5): 1372 (fish school size & migration)

Washington State
J 26(1): 55 (benthic infauna standing crop off coast)
(2): 299 (planktonic & benthic bacteriovorous Protozoa)
(7): 1727 (synopsis & key to Ophiuroidea)

Waters, natural (*see also* Limnology; Oceanography)
J 26(7): 1948 (2 useful devices for vertical sampling)

Watershed
J 26(6): 1439 (Missouri–Saskatchewan R., re fishes distribution)

Watson, Jeffrey
A 136 (submersibles for fisheries research)
138 (queen crab industry in Atl. Provinces)

Weather (*see* Climate; Storms)

Weber, Douglas Duane
J 26(5): 1263 (sockeye survival re finclipping)

Wedemeyer, Gary
J 26(1): 115 (endotoxins in salmonids)

Weight (*see also* Growth; Length; Size)
J 26(1): 123 (allometric weight–length regression model)
(1): 161 (comparison of 2 fish growth in weight equations)
(7): 1813 (bluegill body weight effect on endogenous nitrogen secretion)
(10): 2561 (of white whale organs & other components)
(10): 2643 (re oxygen consumption metabolism: mathematical relations for several fishes)
(10): 2741 (on length regression for rapid average length determination of young sockeye salmon)
(12): 3133 (cod off SW Nfld.; also weight–length relation for round & gutted)
CVG 41 (changes of some B.C. fishes held at sea in refrigerated sea water vs. ice)
T 94–97 (Nfld. herring data, 1964–65 to 1967–68)
135 (weight–length relations for 6 B.C. groundfish species)
S 1317 (re length, Atl. salmon off Nfld.)

Weinsieder, Allan
A 132 (the FRB — what does it do to help fishermen)

Wellings, Seftoa Robert
J 26(8): 2215 (infection of English sole)

Westenhouse, Ray George
J 26(6): 1664 (dichromate reagent decomposition)

Westrheim, Sigurd Jergen
T 113 (*G. B. Reed* groundfish cruise 69-1)
132 (*G. B. Reed* groundfish cruise 69-2)

Whale (*Mesodon carlhubbsi*)
B 171 : 9 (records, B.C.)

Whale, Baird's beaked (*Berardius bairdi*)
B 171 : 5 (description, records, etc., of B.C.)

Whale, black right (*Balaena glacialis*)
B 171 : 38 (description, records, etc., of B.C.)

Whale, blue (*Balaenoptera musculus*)
B 171 : 36 (description, records, etc., of B.C.)
A 122 (an 80-ft, at B.C. whaling station)

Whale, Cuvier's beaked (*Ziphius cavirostris*)
B 171 : 11 (description, records, etc., of B.C.)

Whale, false killer (*Pseudorca crassidens*) (a dolphin)
B 171 : 24 (record from Puget Sound, Wash., though not yet from B.C.)

Whale, fin (finback) (*Balaenoptera physalus*)
B 171 : 33 (description, records, etc., of B.C.)

Whale, gray (*Eschrichtius gibbosus*)
B 171 : 30 (description, records, etc., of B.C.)

Whale, humpback (*Megaptera novaeangliae*)
B 171 : 37 (description, records, etc., of B.C.)

Whale, killer (*Orcinus orca*) (a dolphin)
B 171 : 19 (description, records, etc., of B.C.)

Whale, little piked (*see* Whale, minke)

Whale, minke (*Balaenoptera acutorostrata*) (little piked whale)
B 171 : 34 (description, records, etc., of B.C.)

Whale, Pacific pilot (*Globicephala macrorhyncha*) (a dolphin)
B 171 : 24 (description, records, etc., of B.C.)

Whale, sei (*Balaenoptera borealis*)
B 171 : 34 (description, records, etc., of B.C.)

Whale, sperm (*Physeter catodon*)
B 171 : 13 (description, records, etc., of B.C.)
A 122 (a 56-ft. at B.C. whaling station)

Whale, Stejneger's beaked (*Mesoplodon stejnegeri*)
B 171 : 9 (records from B.C.)

Whale, white (*Delphinapterus leucas*)
J 26(8): 2201 (tagging in Canadian arctic)
(8): 2205 (wintering in James Bay)
(10): 2561 (body size; weight of organs & other components)

Whales
J 26(1): 179 (computer programming data re estimation of exploited populations)
B 171 : 9 (*Mesoplodon* records from B.C.)

Whaling (*see also* names of individual whales)
B 171 : 49 (catches, B.C., 1905–67)
A 122 (pictorial review of B.C. industry)

Whelk (*see* Oyster drill)

Whitaker, R. S.
J 26(6): 1694 (Atl. salmon muscle damage in gillnets)

White, D. R. L.
J 26(6): 1694 (Atl. salmon muscle damage in gillnets)

White, G. N.
J 26(3): 701 (mass mortality of fauna at Bideford, P.E.I.)

White Lake, B.C.
J 26(7): 1763 (meromixis & other characteristics)

Whitefish, broad (*Coregonus nasus*)
J 26(8): 2252 (age & growth, Mackenzie & Coppermine R., N.W.T.)

Whitefish, lake (*Coregonus clupeaformis*)
J 26(2): 325 (S Alta. distribution)
(4): 849 (*Cystidicola* nematodes in swim bladder)
(9): 2521 (hermaphroditism)
(12): 3266 (diel activity judged by gillnet catchability)
B 151(F) (smoking; canning)
S 1269 (parasite detection by ultrasound)

Whitefish, mountain (*Prosopium williamsoni*)
J 26(2): 325 (S Alta. distribution)
(6): 1439 (distribution in Canadian Missouri R. headwaters)

Whitefish, ocean (*Caulolatilus princeps*)
J 26(5): 1371 (N range extension)

Whitefish, round (*Prosopium cylindraceum*)
J 26(10): 2681 (shape & structure re gillnet selectivity)

Whitworth, Walter Richard
J 26(9): 2493 (brook trout growth)

Wickett, William Percy
T 126 (N Pac. Ocean transport computations)
127 (N Pac. Ocean surface transport charts, 1968)
128 (N Pac. Ocean Ekman transport, 1946–68)

Wiener (*see* Sausage)

Wilder, Donald George
A 121 (TBTO treatment for lobster traps)

Wiles, Michael
J 26(12): 3242 (Atl. cod ovaries fibrous and cystic lesions)
S 1318 (biology & fishery of the W Nfld. cod stock)

Willock, Thomas Andrew
J 26(6): 1439 (Missouri drainage fishes)

Wilson, Dennis Carl
J 26(9): 2339 (reproduction of shiner perch)

Windell, John Thomas
J 26(7): 1801 (rainbow trout on pellet diets)

Wise, John P.
J 26(6): 1676 (*Lolliguncula brevis* measurements)

Wiseman, Phyllis Maxwell
S 1264 (Alaskan king crab & N Atl. queen crab sterols)

Witch (*see* Flounder, witch)

Withler, Frederick Curtis
T 111 (salmon ova & milt)

Wolf, Ken
J 26(6): 1459 (infectious pancreatic necrosis detection methods)
(9): 2511 (trout re infectious pancreatic necrosis)

Wolfert, David Richard
J 26(7): 1887 (L. Erie walleyes)

Wolffish, Atlantic (*Anarhichas lupus*)
J 26(2): 311 (copepod parasitic on gills)
CJG 16 (Nfld. landings, 1953–68, & details for 1968)

Wong, Joseph
CVG 42 (salmon canning waste-water clarification)

Wood, Albert Lewis
J 26(12): 3271 (freeze-dried cod steaks quality)
CHN 35 (fillet freezing time & weight loss)

Wood borers (*see* Gribble; shipworms)

Woods, Susan Madeleine
J 26(3): 543 (polyteny in *Pseudocalanus* sp.)

Worm, boring sea (*Polydora ciliata*)
B 169 : 155 (parasite of Pac. oyster in B.C.

Worms, marine (*see also* classifications)
A 133 (caloric value of 9 kinds)

Worms, spiny-headed (*see* Acanthocephala)

Woronecki, David E.
J 26(3): 709 (northern redbelly dace occurrence)

Wowchuk, Robert Michael
T 113 (*G. B. Reed* groundfish cruise 69-1)

X

Xanthophyceae (*see also* Seaweeds)
J 26(10): 2703 (*Vaucheria* sp., Halifax, Co., N.S.)

Xeneretmus latifrons (*see* Poacher, blacktip)

Xiphias gladius (*see* Swordfish)

Xiphister atropurpureus (*see* Prickleback, black)

Y

Yamaguti, Satyu
J 26(4): 845 (digenetic trematode nutrition)

Yamazaki, Fumio
S 1292 (salmon pituitary gonadotropin in goldfish)
1336 (hormones & spermiation in goldfish)

Yates, Arthur Nelson
CNG 87 (experimental prawn trap fishing)
A 128 (B.C. prawn trap fishing)

Yeasts
J 26(12): 3165 (as winter zooplankton feed, Strait of Georgia, B.C.)
S 1305 (biomass re marine feeding of young Pac. salmons & trout)

Yellow Lake, B.C.
J 26(7): 1763 (meromixis & other characteristics)

Yellowstone Lake, Wyoming
J 26(5): 1243 (cutthroat trout movements & homing)

Yevich, Paul Peter
J 26(2): 433 (cyprinodontiform blood morphology)

Yield (*see also* Angling; Catches)
J 26(3): 479 (size-selective mortality & sampling bias effects on estimates of)
(5): 1205 (equilibrium, in exploited American plaice stock)
(8): 1985 (analytical approach to forecasts, NE Pac. ocean demersal fishing)
(10): 2715 (effects of simulated long-term environmental fluctuations on maximum sustained)
(11): 2969 (meat yield from *Parapenaeus* Atl. shrimps)
B 169 : 120 (meat yield from Pac. oyster)
T 92 (computer programming for equilibrium yield per recruitment of a fish stock)

Yoldia limulata (Atl. pelecypod)
J 26(3): 701 (heavy mortality from unusually low P.E.I. estuarine salinity)

Yonemori, Tamotsu
S 1302 (N Pac. Ocean salmon)

Yuen, Kenneth Buck
J 26(9): 2477 (tidal barrier effects on M_2 tide)

Z

Zalophus californianus (*see* Sea lion, California)

Zinc compounds (*see also* Mineral content)
J 26(1): 145 (marine organisms requirement estimates)
(5): 1347 (re calanoid copepods culture)
B 169 : 149 (in Pac. oyster)
T 114 (content of Atl. & Pac. herring meals)
S 1291 (antipollutant agent for protecting fish from)

Ziphius cavirostris (*see* Whale, Cuvier's beaked)

Zooplankton (*see also* Feed; Plankton; *also* subclassifications)
J 26(2): 199 (production estimation from phytoplankton, NE Pac. Ocean; corrections on J 26(8): 2264)
(2): 299 (bacteriovorous Protozoa, Puget Sound, Wash.)
(2): 305 (biomass re Arctic Basin & East Greenland Current hydrography)
(6): 1485 (population & production ecology, Ogac L., Baffin Is.)
(6): 1605 (predation of standing stocks by *Cyclops*)
(7): 1948 (vertical sampler)
(8): 2240 (sampling net for surface)
(9): 2345 (caloric & carbon equivalents of biomass)
(9): 2459 (seasonal distribution, constitution & abundance, L. Erie)
(10): 2543 (life cycle, seasonal abundance, & vertical distribution of copepods, Parry Sound, Ont.)
(12): 3101 (changes after several fertilizations of a lake)
(12): 3165 (bacteria & other heterotrophs as winter feed for, Strait of Georgia, B.C.)
T 110 (Strait of Georgia biomass, 1965–67)

Zostera marina (*see* Eelgrass)

Zwicker, Betty Mary
J 26(9): 2503 (temperature on gaffkemia)
S 1344 (gaffkemia in lobsters)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

LIST OF PUBLICATIONS

JOURNAL OF THE FISHERIES RESEARCH BOARD OF CANADA

Abbreviation : J

(A complete list of the contents for the 1969 Volume 26 is included at the back of this issue for binding purposes.)

BULLETINS OF THE FISHERIES RESEARCH BOARD OF CANADA

Abbreviation : B

168. QUAYLE, D. B. Paralytic shellfish poisoning in British Columbia. x + 68 p.

169. QUAYLE, D. B. Pacific oyster culture in British Columbia. xii + 192 p.

170. SÆTHER, OLE A. Some Nearctic Podonominae, Diamesinae, and Orthocladiinae (Diptera: Chironomidae). ix + 154 p.

171. PIKE, G. C., AND I. B. MACASKIE. Marine mammals of British Columbia. ix + 54 p.

172. BIGG, MICHAEL A. The harbour seal in British Columbia. viii + 33 p.

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151. LANTZ, A. W. Produits spéciaux des poissons d'eau douce. ix + 59 p. [English edition published in 1966.]

CIRCULARS OF THE FISHERIES RESEARCH BOARD OF CANADA

Halifax Laboratory, Halifax, N.S.

Abbreviation : CHN

35. WOOD, A. L., AND L. W. REGIER. Freezing time and weight loss for fillets and bite-size pieces in air blast at −17°F. 2 p.

Biological Station, Nanaimo, B.C.

Abbreviation : CNG

87. YATES, A. N. Experimental prawn trap fishing December 1, 1967 to March 22, 1968. 29 p.

Biological Station, Nanaimo, B.C.
(Statistical Series)

Abbreviation : CNS

27. BILTON, H. T., D. W. JENKINSON, E. W. STOLZENBERG, AND M. M. AARTS. Age composition of 1965 British Columbia sockeye, chum and pink salmon catches. 246 p. [1966]

28. Forrester, C. R. Trawl production by Canadian and United States vessels from grounds adjacent to British Columbia during the years 1954 to 1965, inclusive. 26 p. + 12 app. [1967]

Biological Station, St. John's, Nfld.

Abbreviation : CJG

16. Fleming, A. M. [ed.] [various authors]. Fishery investigations and groundfish landings in Newfoundland, 1968. 35 p.

Vancouver Laboratory, Vancouver, B.C.

Abbreviation : CVG

41. Tomlinson, Neil, D. E. Kramer, S. E. Geiger, and S. W. Roach. Weight changes in some species of Pacific coast fish while stored at sea in refrigerated sea water or in ice. 26 p.

42. Claggett, F. G., and J. Wong. Salmon canning waste-water clarification. Part II. A comparison of various arrangements for flotation and some observations concerning sedimentation and herring pump water clarification. 25 p.

43. Tomlinson, N., D. E. Kramer, S. E. Geiger, Geiger, S. W. Roach, and J. H. Mann. Storage of Pacific salmon at sea. 1. Influence of delay in chilling the catch on quality of the canned product. 15 p.

44. Tomlinson, N., D. E. Kramer, S. E. Geiger, and S. W. Roach. Storage of Pacific salmon at sea. 2. Influence of delay in chilling the catch and of the method of chilling (ice or refrigerated sea water) on the yield at various steps in the handling, storage and canning of sockeye salmon (*Oncorhynchus nerka*). 12 p.

ANNUAL REPORT

Abbreviation : AR

Annual Report Fisheries Research Board of Canada 1968. 35 p. (combined English and French).

REVIEW

Abbreviation : R

Review of the Fisheries Research Board of Canada 1967/1968. 155 p.

MISCELLANEOUS SPECIAL PUBLICATIONS

Abbreviation : MSP

12. An invitation to carry on research in the aquatic sciences at the Biological Station of the Fisheries Research Board of Canada, St. Andrews, New Brunswick. 16 p.

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10. The Fisheries Research Board of Canada — What it is and what it does. 1968. 18 p. [Reprinted.]

TECHNICAL REPORTS OF THE
FISHERIES RESEARCH BOARD OF CANADA

Abbreviation : T

79. STODDARD, JUDITH H. Fat contents of Canadian Atlantic herring. 23 p. + 11 tables + 18 fig. (St. Andrews Biological Station) [1968]

86. MCCRACKEN, F. D. Cod and haddock catches by Maritime trawlers on the Scotian Shelf and Georges Bank, 1965. 3 p. + 25 fig. (St. Andrews Biological Station) [1968]

88. DAS, NARESH. Spawning, distribution, survival, and growth of larval herring (*Clupea harengus* L.) in relation to hydrographic conditions in the Bay of Fundy. 129 p. + 27 fig. (St. Andrews Biological Station) [1968]

90. MARSHALL, K. E. Periodical citations in the recent literature of freshwater and fisheries biology. 67 p. (Freshwater Institute, Winnipeg)

91. FORSYTHE, MICHAEL GEORGE. Analysis of the 1966 smolt run in the Northwest Miramichi River, New Brunswick. 33 p. (St. Andrews Biological Station)

92. PIENAAR, L. V., AND J. A. THOMSON. Equilibrium yield per recruitment A 1130 Fortran version of Program No. FRG 708. 22 p. (Nanaimo Biological Station)

93. HOYLE, R. J., B. TRUSCOTT, AND D. R. IDLER. Studies on freezing sperm of Atlantic salmon (*Salmo salar*). 42 p. (Halifax Laboratory)

94. HOURSTON, A. S., R. D. HUMPHREYS, AND J. A. THOMSON. Herring sampling data and summary tabulations for Newfoundland, 1964–65. 80 p. (St. John's Biological Station)

95. HOURSTON, A. S., V. M. HODDER, AND J. A. THOMSON. Herring sampling data and summary tabulations for Newfoundland, 1965–66. 94 p. (St. John's Biological Station)

96. HOURSTON, A. S., R. CHAULK, AND J. A. THOMSON. Herring sampling data and summary tabulations for Newfoundland, 1966–67. 172 p. (St. John's Biological Station)

97. HOURSTON, A. S., R. CHAULK, S. PARSONS, AND J. A. THOMSON. Herring sampling data and summary tabulations for Newfoundland, 1967–68. 220 p. (St. John's Biological Station)

98. MURRAY, A. R. Some climatic and geomorphic aspects of the Little Codroy River, Newfoundland. 185 p. (St. John's Biological Station)

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100. FORRESTER, C. R., AND D. F. ALDERDICE. Preliminary observations on embryonic development of the flathead sole (*Hippoglossoides elassodon*). 20 p. (Nanaimo Biological Station)

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103. MERCER, M. C. *A. T. Cameron* cruise 130, otter-trawl survey from southern Nova Scotia to Cape Hatteras, March–April 1967. 24 p. (St. John's Biological Station)

104. BOURNE, N. Scallop resources of British Columbia. 60 p. (Nanaimo Biological Station)

105. FORRESTER, C. R. Life history information on some groundfish species. 17 p. (Nanaimo Biological Station)

106. COLLINS, C. A., R. L. TRIPE, D. A. HEALEY, AND O. JOERGENSEN. The time distribution of serial oceanographic data from the Ocean Station P program. 10 p. + 4 app. (Nanaimo Biological Station)

107. KENNEDY, W. A. Sablefish culture—a preliminary report. 20 p. (Nanaimo Biological Station)

108. FORRESTER, C. R., AND J. A. THOMSON. Population studies on the rock sole (*Lepidopsetta bilineata*) of northern Hecate Strait, British Columbia. 104 p. (Nanaimo Biological Station)

109. KITANO, Y. The age and growth of the yellowfin sole (*Limanda aspera*) in Hecate Strait, British Columbia. 36 p. (Nanaimo Biological Station)

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111. MORLEY, R. B., AND F. C. WITHLER. Observations on sockeye and pink salmon ova and milt relative to spawn collection. 11 p. (Nanaimo Biological Station)

112. PIENAAR, L. V., AND J. A. THOMSON. A program for multiple discriminant analysis (Fortran 1130) extended version. 26 p. (Nanaimo Biological Station)

113. Westrheim, S. J., D. Davenport, W. R. Harling, M. S. Smith, and R. M. Wowchuk. *G. B. Reed* groundfish cruise No. 69-1, February 11–27, 1969. 23 p. (Nanaimo Biological Station)

114. Power, H. E., K. A. Savagaon, B. E. March, and Jacob Biely. The chemical and nutritive characteristics of herring meals produced on the Atlantic coast of Canada. 14 p. (Halifax Laboratory)

115. Krauel, David P. A physical oceanographic study of the Margaree and Cheticamp River estuaries. 152 p. (Marine Ecology Laboratory, Dartmouth)

116. Rowe, V. Leslie, and A. V. Tyler. Observations on the polychaete, *Clymenella torquata*, with emphasis on egg production. 6 p. + 5 fig. (St. Andrews Biological Station)

117. Prest, Janice. Catch and effort statistics of the British Columbia trawl fishery in 1968. 93 p. (Nanaimo Biological Station)

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127. WICKETT, W. PERCY, AND J. A. C. THOMSON. Surface transport charts for the North Pacific Ocean, 1968. 29 p. (Nanaimo Biological Station)

128. WICKETT, W. PERCY, AND J. ARTHUR THOMSON. Computation of divergence of Ekman transport for the North Pacific Ocean, 1946–1968. 281 p. (Nanaimo Biological Station)

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130. MURRAY, A. R., AND T. J. HARMON. A preliminary consideration of the factors affecting the productivity of Newfoundland streams. 405 p. (St. John's Biological Station)

131. FORRESTER, C. R., AND J. E. SMITH. A summary report of the British Columbia trawl fishery in 1968 and some aspects of its investigation. 41 p. (Nanaimo Biological Station)

132. WESTRHEIM, S. J., D. DAVENPORT, M. S. SMITH, AND D. M. BIANCHIN. *G. B. Reed* groundfish cruise No. 69-2, June 18–July 2, 1969. (Nanaimo Biological Station)

133. BILTON, H. T., AND D. H. [H. D.] SMITH. Scale characteristics of sockeye salmon (*Oncorhynchus nerka*) originating from small nursery areas of the Skeena River system. 33 p. (Nanaimo Biological Station)

134. PIPPY, JOHN H. C. Preliminary report on parasites as biological tags in Atlantic salmon (*Salmo salar*). I. Investigations 1966 to 1968. 44 p. + 5 fig. + 8 tables. (St. Andrews Biological Station)

135. FORRESTER, C. R., AND J. A. THOMSON. Length–weight relationships in some marine groundfish. 16 p. (Nanaimo Biological Station)

136. TIBBO, S. N., AND L. M. LAUZIER. On the origin and distribution of larval swordfish *Xiphias gladius* L. in the western Atlantic. 20 p. (St. Andrews Biological Station)

137. [Not yet published and not included in this index.]

138. [Not yet published and not included in this index.]

139. TIBBO, S. N., S. N. MESSIEH, AND C. D. BURNETT. Catch statistics — length and age composition, Gulf of St. Lawrence herring. 5 p. + 4 fig. + 67 tables.

STUDIES OF THE FISHERIES RESEARCH BOARD OF CANADA

Abbreviation : S

1263. PARKER, ROBERT R. 1968. *Caligus longicaudatus* Brady, 1899 (Caligidae: Copepoda). Bull. Brit. Museum (Nat. Hist.) 15: 353–368.

1264. IDLER, D. R., AND P. WISEMAN. 1968. Desmosterol and other sterols of the Alaskan king crab and the North Atlantic queen crab. Comp. Biochem. Physiol. 26: 1113–1117.

1265. ACKMAN, R. G. 1968. The flame ionization detector: further comments on molecular breakdown and fundamental group responses. J. Gas Chromatog. 6: 497–501.

1266. ELDJARN, L., K. TRY, R. G. ACKMAN, AND S. N. HOOPER. 1968. Different ratios of the LDD and DDD diastereoisomers of phytanic acid in patients with Refsum's disease. Biochem. Biophys. Acta 164: 94–100.

1267. MARGOLIS, L. 1968. Review of the Japanese species of *Cystidicola*, *Metabronema* and *Rhabdochona* (Nematoda) from salmonid fishes. Res. Bull. Meguro Parasitol. Museum 2: 23–44.

1268. RICKER, W. E., RENE MALOUIN, PETER HARPER, AND H. H. ROSS. 1968. Distribution of Quebec stoneflies (Plecoptera). Naturaliste Canadien 95: 1085–1123.

1269. FREESE, M., AND D. MAKOW. 1968. High-frequency ultrasonic properties of freshwater fish tissue. J. Acoust. Soc. Am. 44: 1282–1289.

1270. STRASDINE, G. A. 1968. Amylopectin accumulation in *Clostridium botulinum* type E. Canadian J. Microbiol. 14: 1059–1062.

1271. LARKIN, P. A., AND J. G. MCDONALD. 1968. Factors in the population biology of the sockeye salmon of the Skeena River. J. Animal Ecol. 37: 229–258.

1272. SHIEH, H. S. 1968. The characterization and incorporation of radioactive bases into scallop phospholipids. Comp. Biochem. Physiol. 27: 533–541.

1273. DUEDALL, IVER W. 1968. Partial molal volumes of 16 salts in sea water. Environ. Sci. Technol. 2: 706–707.

1274. DUEDALL, IVER W. 1968. A mercury dispenser. J. Chem. Educ. 45: 393.

1275. DUEDALL, IVER W. 1967. A nonwetting surface on glass. Am. J. Physics 35: iii–iv.

1276. SPRAGUE, J. B., AND D. W. MCLEESE. 1968. Toxicity of bleached kraft mill effluent to larval and adult lobsters and Atlantic salmon. Pulp Paper Magazine Canada, December 1968: T431–T433.

1277. SPRAGUE, J. B., AND D. W. MCLEESE. 1968. Toxicity of kraft mill effluent for larval and adult lobsters, and juvenile salmon. Water Res. 2: 753–760.

1278. SPRAGUE, J. B., AND D. W. MCLEESE. 1968. Different toxic mechanisms in kraft pulp mill effluent for two aquatic animals. Water Res. 2: 761–765.

1279. MAY, A. W., AND J. MESSTORFF. 1968. Comparative fishing by research vessels *A. T. Cameron* and *Walther Herwig*. ICNAF Redbook 1968, Part III. p. 21–27.

1280. TEMPLEMAN, WILFRED. 1968. Temperatures and salinities, 1967 at Station 27 and in the St. John's–Flemish Cap section. ICNAF Redbook 1968, Part III. p. 37–39.

1281. CARROTHERS, P. J. G. 1968. Field identification of synthetic fibres used in fish nets. ICNAF Redbook 1968, Part III. p. 49–52.

1282. BECKETT, J. S., AND S. N. TIBBO. 1968. Recent changes in size composition of Canadian Atlantic swordfish catches. ICNAF Redbook 1968, Part III. p. 62–66.

1283. Hourston, A. S. 1968. The Newfoundland herring fishery and its implications concerning the resource. ICNAF Redbook 1968, Part III. p. 67–73.

1284. Caddy, J. F., and E. I. Lord. 1968. Recent developments in the Georges Bank scallop fishery. ICNAF Redbook 1968, Part III. p. 89–93.

1285. Khouw, B. T., H. D. McCurdy, and R. E. Drinnan. 1968. The axenic cultivation of *Hexamita inflata* from *Crassostrea virginica*. Canadian J. Microbiol. 14: 184–185.

1286. Ackman, R. G., R. F. Addison, and C. A. Eaton. 1968. Unusual occurrence of squalene in a fish, the eulachon *Thaleichthys pacificus*. Nature 220: 1033–1034.

1287. Scott, J. S. 1969. *Lampritrema nipponicum* (Trematoda) from west Atlantic argentines. Canadian J. Zool. 47: 139–140.

1288. Stewart, James E., and M. F. Li. 1969. A study of lobster (*Homarus americanus*) ecology using serum protein concentration as an index. Canadian J. Zool. 47: 21–28.

1289. Tarr, H. L. A. 1969. *De novo* biosynthesis of inosinic and uridylic acids by salmon testes and liver. Canadian J. Biochem. 47: 197–201.

1290. Dyer, W. J. 1968. Deterioration and storage life of frozen fish, p. 429–447. *In* Prof. J. Hawthorne [ed.] Low temperature biology of foodstuffs. Pergamon Press, Oxford, New York.

1291. Sprague, John B. 1968. Promising anti-pollutant: chelating agent NTA protects fish from copper and zinc. Nature 220: 1345–1346.

1292. Yamazaki, Fumio, and Edward M. Donaldson. 1968. The effects of partially purified salmon pituitary gonadotropin on spermatogenesis, vitellogenesis, and ovulation in hypophysectomized goldfish (*Carassius auratus*). Gen. Comp. Endocrinol. 11: 292–299.

1293. Parker, Robert R. 1968. *Caligus appendiculatus* F. Müller, 1852 (Crustacea: Copepoda): A request for suppression under the plenary powers. Z.N.(S.) 1839. Bull. Zool. Nomenclature 25: 105–106.

1294. Parsons, T. R., and D. J. Blackbourn. 1968. Pigments of the ciliate *Mesodinium rubrum* (Lohmann). Neth. J. Sea Res. 4: 27–31.

1295. Parsons, T. R., and R. J. LeBrasseur. 1968. A discussion of some critical indices of primary and secondary production for largescale ocean surveys. Calif. Marine Res. Comm. CalCOFI Rept. 12: 54–63.

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